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GAS JOURNAL

LIGHT ✦ HEAT ✦ POWER ✦ BYE-PRODUCTS

[Founded in 1849 as the "Journal of Gas Lighting."]

VOL. CLXXII. No. 3260.] LONDON, NOVEMBER 4, 1925. [77TH YEAR. PRICE 1s.

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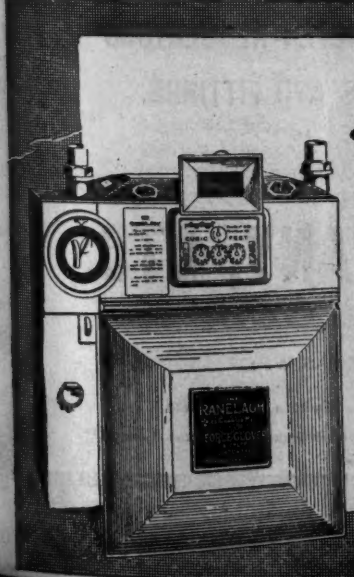

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EDITORIAL NOTES.

Coke and the Fuel Research Station.

FROM information conveyed by the report for the year 1924-25 of the Committee of the Privy Council for Scientific and Industrial Research, reference was made in last week's issue to the work at the Fuel Research Station. Since then the report of the Fuel Research Board has come to hand; and this gives a general but fuller account of the activities past, present, and in prospect at the close of last year. The area and variety of the work are as important as they are great; and, as readers of the "JOURNAL" are aware, the results of a considerable part of the work have been of immense value to the gas industry. In view of this we cannot look with envy upon the persistent pursuit there has been of the problems connected with low-temperature carbonization. The Fuel Research Station is a national one; and the Board have been anxious to serve the country in two ways—by exploring the potentialities of carbonization at low temperatures for the purpose of making the country less dependent upon imported oil, and for providing it with a smokeless fuel. But so far, all that has been done has not resulted in any proof of the system *per se* attaining a commercial status; and the resulting coke has not had all the characteristics which are required—not from the point of view of combustion, but from that of stability. While not overlooking the dual objective of the extensive trials under divers conditions, with coals and blends of coals in different states, including briquetting, we do think that, in respect of coke, it would have been of greater advantage if trials had been made simultaneously to ascertain the effects of carbonizing at both low and high temperatures the prepared blends of coal, with and without briquetting. Comparisons of characteristics—including structure, ignitibility, and combustibility—of the high and low temperature cokes could then have been made which would have been highly informative. However, the reports of the Chairman of the Board (Sir Richard T. Threlfall) and the Director of Fuel Research (Dr. C. H. Lander) convince us that the work that has been done in this direction, though low temperatures were employed, will be, within limits, of value to the industries working at high temperatures. We say "within limits," because the structure and other characteristics of the coke would be very largely altered by carbonizing at high as compared with low temperatures; and we want to get to definite facts regarding the value of structure as opposed to volatile matter content.

The importance of this is shown in one part of Dr. Lander's report, where he says that the difficulties that have to be overcome in the low-temperature carbonization of coal are greater than where high temperatures are used. He goes on to say that coal is a complex collection of substances, which, with increasing temperatures, are decomposed gradually into less complex liquid and gaseous substances. "What substances result from this decomposition, and what is the physical as well as the chemical character of the coke that is left, depend not only on the composition of the coal, but on the temperatures attained, and the period that the coal and its products are exposed to them." Those are well-known facts; but in them is the case for our submission that much that would have been instructive and practical would have resulted had investigation proceeded side by side, in this particular matter, with both low and high temperature carbonization. We fully agree that, until we know more about the subject of blending coals for carbonization and the practical and economic consequences of it, complete control will not have been established over carbonization on the technical scale, nor will there be satisfaction that the best national service is being given in the provision of a solid smokeless fuel. In the national interests (we put it plainly) the work of the Fuel Research Station should be directed to ascertaining whether economic advantage in the production of such a fuel lies in high or low temperature carbonization. The dual purpose that has been kept prominently to the fore—oil and smokeless fuel—may have to suffer a little sacrifice on one hand in order to gain the maximum advantage on the other.

However, the work at the station is developing; and as the lines of development are brought into orderly relationship, it can be seen that they will have considerable effect upon the future of carbonizing processes and practices, through the knowledge obtained as to coals and the preparation that is necessary to derive from them maximum qualitative results. The Physical and Chemical Survey of the Coal-Fields that is being made under the direction of the Board will be of incalculable value. The investigation of coal purification processes and the most suitable treatment for any given coal must be of good technical influence. This is a large and far-reaching subject in connection with coke production. Dr. Lander's report clearly shows that in this direction the Research Station is opening up a new avenue of work which, it is believed, will have highly important results. In the first place, it is pointed out that while it is obviously undesirable that large quantities of incombustible material should be mixed with coal as marketed, the amount of purification desirable or economically possible depends on circumstances. Again, the impurities in coal as raised have different origins; and they occur in various forms, distributed throughout the coal in various ways. Hence the purification process may remove different impurities in varying proportions, with the result that not merely the quantity but the quality of the resultant ash may be altered. The composition of the resulting ash may be of considerable importance; and recent work indicates that this may exercise a subtle influence on the decomposition of coal when heated. Dr. Lessing's work on the catalytic effect of individual inorganic compounds on the yield of volatile therms in the form of gas and tar is probably the "recent work" to which allusion is made. The research is also in hand on the combustibility of coke, and the factors on which it depends; and simultaneously the evolution is proceeding of a standard method for the determination of the hardness and strength of coke.

From what has been said in this article, it will be seen that matters relating to coke production are occupying a prominent place in the work of the Fuel Research Station. Other features of the activities will be noticed in a general review of the report in an early issue.

Heating Value in America.

A REMARKABLY complete survey and criticism of the work that has been done in this country and the United States regarding the relative usefulness of gases of different heating values has been made by Mr. E. R. Weaver, of the Bureau of Standards, Department of Commerce, Washington. It is the most comprehensive collection of data on the subject which has yet been published; and we heartily compliment the compiler and critic upon the thoroughness with which he has done his work. As in this country, so in America, the subject has been of great interest, and of more or less active controversy. This is not astonishing, as there can be no question respecting the importance of determining what relation does exist between the quality of gas and its usefulness. In this country the matter was set at rest, in so far as the major part of our technical gas men are concerned, by the work of the Gas Investigation Committee of the Institution of Gas Engineers and the Leeds University; and it is satisfactory to find that the vast amount of investigation that has been made in America enables Mr. Weaver to issue from his critical exploration with the view that the reliable work of both countries is confirmatory in its main results.

One conclusion is that the evidence goes to show that, in any range of commercial gases, the advantage in thermal efficiency of gas of the lower heating values is entirely negligible. There has been more or less vague talk in some quarters as to a volume of gas of low heating value doing the same work as a like volume of gas of a higher calorific value; and the only explanation given for this is that it is possible to obtain a better admixture of air and gas, and that less air is required to complete combustion per cubic foot of gas. But it has been obvious that any advantage in that direction is insufficient to justify the assertion that there is no difference in the volume of gas consumed with the lower as compared with the higher calorific value. From his comprehensive study, Mr. Weaver says that the general statement appears to be entirely justified that, in spite of the many complicating factors which affect consumption, the change in the volume of gas used is equal to, or somewhat greater than, the change in heating value—in other words, the volumetric change is approximately proportional to the thermal change. The increase in volume is sometimes more and sometimes less than would be expected from a change of heating value alone; but weather and economic conditions no doubt account for such variations up or down of an appreciable character. The argument that complaints are reduced with the lowering of calorific value is shown by the evidence to be warranted in some cases, and not in others. Where, however, the statement is valid, it is not an effect of lowering the heating value of the gas, but of the readjustment of appliances that is made by a house-to-house visitation by qualified men. Where this attention is not given, the complaints increase with the change of calorific value, and this would be the same whether the change (providing it is of serious amount) be up or down.

In effect, other conclusions found in this report supply from America ample justification of our Gas Regulation Act. The evidence, Mr. Weaver finds, is conclusive that the consumer is concerned only with the amount of heat delivered, and not with the volume, composition, or any other property of the gas which he buys; and this greatly simplifies the consideration of both rates and standards. What is said on this point may be quoted: "Since it makes "no difference in the use of gas how many cubic feet are "required to deliver a million B.Th.U., the consumer is "not concerned with the cost per 1000 c.ft. The users "of gas are concerned only in receiving a continuous "supply of gas at satisfactory pressure and at the lowest "possible cost per B.Th.U. It directly follows from this "that the heating value standard which is best in any "locality is that which will permit the distribution of the "quantity of potential heat required by the community "served at the lowest possible cost to the gas company." In another respect, the report indirectly supports the principle of a movable calorific standard as conditionally allowed by the Gas Regulation Act. It is pointed out that the determination of the heating value which will permit of the distribution of potential heat at the least total cost is a complicated engineering and business problem, involving the consideration of several factors. Some of these are subject to change; and therefore the most economical value one year may not be the most economical five years later. It is held that for this reason it is usually not desirable to prescribe heating value standards to remain in force for a long period of time. On this point the report says:

> When there is no authority, such as a State Public Utility Commission, which is competent to determine both rates and standards, it has been customary to grant franchises for a period of years, specifying the price of gas per 1000 c.ft. and the heating value. This, in reality, amounts to fixing the price of potential heat by contract, but without leaving any easy method for the gas company to adjust its practice to meet changing economic conditions and engineering progress. The Bureau of Standards has long favoured the inclusion in such a franchise of a provision allowing the gas company the option of changing the heating value at will, provided it does not change the essential part of the contract, which is the price of potential heat to the user. There are several good reasons for leaving this freedom to the gas company. The company's engineers will usually be the first to recognize the possibility of saving by the adoption of a new standard; and the fact that the saving is immediately added to their profits gives an incentive to develop improved methods which will eventually result in benefit to the public.

The main conclusion, that the usefulness to a consumer of a given volume of gas is practically proportional to its heating value, combined with the consequential deductions, should have a large effect upon future gas policy in the U.S.A. We may yet see America adopting the principles of our Gas Regulation Act in regard to the sale of gas on its heating value. It is a rational system, protective of the interests alike of gas consumers and gas undertakings, and conferring latitude to technical and commercial progress which must inure to the advantage of all concerned. We shall take an early opportunity of reviewing the report in greater detail.

First Place in "Conservation."

WE hear a great deal in these times about the "conservation" of this and that. The word is sometimes used loosely, and with narrow connotation. Conservation is usually taken to mean economizing with the view to preservation. The electrical engineer using coal under his steam-boilers may, by various expedients, gain in thermal efficiency; to the extent that he does so, he is contributing to the conservation of coal. The same applies to the coal-carbonizing processes—the greater the intrinsic value of the yield of products per ton, the more we are subscribing to coal conservation. But in the case of the gas and coking industries, they do something more than conserve coal; they preserve its valuable constituents, and make them (in addition to the primary products) available for the world's work. Thus in those industries conservation is practised in the fullest sense of the word. The products may lead to conservation in other ways. For example, the use of gas promotes labour-saving in the home and factory; this means the conservation of human energy. Smokeless coke assisting gas in the purification of the atmosphere results in the conservation of human life and also labour through preventing uncleanliness; and the same conditions conserve and promote the health of the nation's vegetation. The growth of foodstuffs is promoted by the sulphate of ammonia produced from the nitrogen content of the coal. The gas industry may therefore claim to be the greatest assistant Nature has in liberating the wealth of utility she has stored in coal during the ages, as well as the most all-round conservator the country possesses.

Much was heard on the subject of conservation at the annual meeting of the British Commercial Gas Association. Prof. J. W. Cobb dealt with the conservation of the nation's store of solar energy; Dr. R. Veitch Clark, with the conservation of human energy; and Mr. R. S. Ascroft, with the conservation of the nation's vegetation. All these papers have direct interest to the gas industry; but naturally foremost is the contribution of Prof. Cobb. It is far-reaching and conclusive. It examines fuel possibilities, and ends up with the proof that—in respect of the conservation of the nation's store of solar energy, and broadcast utility of products—the process of the gas in-

dustry is *ne plus ultra*, within the limits of the knowledge of to-day, with prospects bright for further advances. This is highly satisfactory. In a preliminary survey, Prof. Cobb shows that the visions of direct utilization of the sun's rays, or of raising "fuel crops" one year for use the next, are (so far as can at present be seen) hopeless of materialization. Because of this, we are driven back to the stores of materials in the earth which represent the result of storing energy from the sun's rays through past ages—in other words, fossilized vegetation in one form or another; and the form which concerns us most is coal, inasmuch as, of all solid fuels, it is the one in which heat energy is stored in the most concentrated form. It is upon coal that this country depends, and is likely to have to depend. The forecast suggests that our existence upon earth at the present time does not warrant us in squandering the great gift which Nature has given us to the grave detriment of our descendants. The selfish individual asks, What has posterity done for us? If we wastefully use our heritage of coal (which we have no right to do), posterity will ask, What have our predecessors done for us? An electrical man, writing in a morning paper recently, expressed the narrow view that the time for coal conservation will come when we are within an appreciable distance of the exhaustion of our coal reserves. But every ton the consumption of which can be displaced by increased efficiency means an immediate advantage to the country through the reduction of costs. The conservation of coal and the preservation of its products are very real factors in our industrial economics, and patriotism and fair-dealing urge us to have some thought for those who will come after, and who will find progressively that, as coal is more difficult and expensive to get, so the manufactured products of this country—iron and steel especially—will, in relation to those countries where the cost of coal is less, stand in a very disadvantageous position. Furthermore, the replacement of hand labour by mechanical operation (which to a large extent is essential) will cause a greater consumption of coal unless we can find means of utilizing it more efficiently.

Therefore, much depends upon the efficiency of the utilization of coal, which involves its use not only as a source of heat and power, but as a source of valuable chemical and fertilizing products. There is full and candid admission by the gas industry that electricity is an indispensable service; but there are some purposes for which its use is prodigal in the expenditure of coal, and therefore, instead of conserving the latter, there is gross waste. It can be easily proved, as Prof. Cobb shows, that the highest efficiency of utilization is obtained by carbonization—both thermally and in products—and that by the high-temperature process. To give definite illustration: The thermal efficiency of the gas-works process is of the same order as the percentage thermal loss that occurs in the best type of generating station, favoured with a good load factor. In other words, the 20 p.ct. thermal efficiency (the major number of stations dip down to 10 p.ct. and below) of the high-class electricity station corresponds to the thermal loss in the best gas-works practice; which loss is only 25 p.ct. of the 80 p.ct. and more in the electricity generating process. There can be forgiveness for the 20 p.ct. expenditure of heat by the gas industry when, in addition to a high thermal efficiency, the result of the process has so many compensations in the shape of raw materials for chemicals and fertilizers. No efficiency in the utilization of electrical energy can counterbalance the tremendous handicap with which it starts at the generating end. It is somewhat humorous to find that, when talking of the efficiency of utilization, our electrical friends use as illustration the ascribed 100 p.ct. efficiency of the electric fire or radiator (which is the most expensive heater in existence), and totally ignore the low efficiencies of utilization in other directions. The 100 p.ct. efficiency for the electric fire is carrying claim to the ultimate possible point, for one reason, as Prof. Cobb points out, that the percentage can only obtain if no air goes into the chimney hot enough to produce the ventilation which is so very essential, and in that case auxiliary ventilating appliances must for health's sake be provided at additional cost. On the other hand, the gas-fire—with its 50 p.ct. of radiant heat and about 25 p.ct. of convected heat—is, as Prof. Cobb says, economical in the way in which it utilizes the heat units supplied by the gas for the combined purpose of heating and ventilating, which it does in a practical and convenient manner.

However the matter is examined, in comparison with electricity generation or low-temperature carbonization, the high-temperature carbonization process comes out on top for efficiency and all-round conservation of our country's fuel resources—conservation in the broadest sense and application of the word. In every way, Prof. Cobb is justified in his concluding statement that, "apart from other considerations, such as those of cleanliness and hygiene, the gas industry is entitled to put forward the claim that, on the basis of thermal efficiency alone, its methods of dealing with our coal supplies represent the highest order of actual achievement in the present. What it may do in the future, it is not possible for any one of us to foresee." He added that the position of the industry is scientifically sound, and that position can, by applying the results of research to technical and economical developments, be made even more assured. We are fully satisfied; but satisfaction must not lead to the mischievous contentment which produces a lessening of effort in the cause of advance. There should be constant mindfulness that competitors are working to lessen the margin of our advantage; our constant ambition and endeavour should be to increase that margin.

Coke Competition Issue.

This will be published next Monday. Any further communications regarding it must reach the "JOURNAL" office not later than the first postal delivery on Friday morning.

Gas Workers' Agreements.

A provincial paper recently published the terms of a circular issued, to the various Unions affected, by Mr. Arthur Hayday, the Secretary on the Workers' Side of the National Joint Industrial Council for the Gas Industry. Wages and conditions of employment, as is known, were stabilized some time ago until the end of the present year; and the circular sought information for the purpose of formulating a policy which could be put into operation either before, or immediately at, the conclusion of the stabilization period. The proposals put forward for consideration were: (1) Whether the executives of the Unions favour the continuance of national agreements in the gas industry, through the machinery of the Joint Industrial Council; or (2) whether they favour the abolition of national agreements, and their substitution by district agreements, or a free selection of undertakings to press any demands agreed upon by the Unions nationally. What the result of this inquiry has been, has not yet been made public; but we should not mind hazarding the opinion that it was not in favour of the abolition of national agreements.

Incongruity.

"It seems strange that, during a period when every endeavour should be made to further the prosperity of this country by encouraging home-produced goods, suggestions should be thrown out to the Government that they ought to carry out research into the problem of rendering a foreign article more suitable for use here, when there is at hand a similar article which does not possess the inherent drawback of the foreign product." This remark was made by Mr. H. E. Bloor, of York, at a luncheon given by the British Road Tar Association at Wembley last week, an account of which appears in later columns of this issue of the "JOURNAL." He was referring to bitumen and tar—two substances which would be equally valuable for road making and surfacing were it not for the fact that while a tar-treated road is perfectly safe, a bitumen surface is slippery. And now, instead of helping a home industry, some actually suggest that the country's money should be spent in an attempt to eradicate this inherent defect of bitumen!

Sheffield Coke Conference.

Particulars regarding this Conference, which is to be held on Nov. 20, are published on p. 279.

The Subvention.

The Mines Department announce that the claims paid to Oct. 31, 1925, under the Coal Mining Industry Subvention total to £3,361,853. The amount for August was £1,608,249; and for September, £1,753,604. At this rate the ten million vote stands a poor chance of holding out to the end of the truce—in fact, it is expected that it will be exhausted by January. In view of this, the Government are considering the question of the introduction of a supplementary estimate.

The Coal Commission.

The outstanding feature of the sittings of the Coal Commission last week was the evidence of Sir Richard Redmayne. There was much in what he had to say which could not be controverted. One suggestion, however, was not of a kind to which the miners' leaders would readily give consent. In Sir Richard's opinion the miners should voluntarily agree to a reversion for three years to an eight-hour day as a means of arresting the decline in output and export; but, of course, this change without a reduction of wages. The whole situation, in his view, could be summed-up in two sentences: Cheapness makes for increased consumption; and increased production makes for cheapness. Among other obvious truths was that nationalization would result in either dearer coal or higher taxation, to enable coal to be produced at a fictitiously low price. Also that salvation for the industry would be found in the aggregation of colliery interests combined with a system of co-partnership as between colliery owners and workmen. A further view was that the supply of oil in the United States would be exhausted in twenty-five years, and the world's supply in 80 to 100 years.

Government Electricity Plans.

Rumours are again in circulation as to the electricity plans of the Government. The scheme, as will be remembered, is at present before a Cabinet Committee presided over by Sir Douglas Hogg. It has been before them for a long time; and they ought now to know it thoroughly. But a Parliamentary writer gathers that both financial details and questions of policy—such, for example, as the ownership of the proposed super-power stations—will have to be settled before a public announcement of the Government's proposals can be made. It is further hinted that the Government are still dreaming of the Severn barrage scheme; and it is thought that additional investigations are desirable. A Sub-Committee of the Committee of Civil Research has been appointed, under the chairmanship of Lt.-Col. Moore-Brabazon, Parliamentary Secretary to the Ministry of Transport; and the project is now to receive expert examination. We hope it is, and that it will be fully disinterested. There has been too much of the politician in control of these highly technical matters.

Hands Off.

The motorists of the country will no doubt unanimously adopt the slogan "Hands Off the Road Fund," suggested by Sir William Letts at the inaugural luncheon of the Commercial Motor Transport Exhibition at Olympia last Thursday. The suggestion was received with hearty cheers, which must have embedded themselves in the ears of Lt.-Col. the Right Hon. W. W. Ashley, Minister of Transport, who was present; and he will probably report what he heard to the Chancellor of the Exchequer and other members of the Cabinet. The motor car makers are of opinion that better roads and more of them are essential to the development of their industry. In the Association of Municipal Corporations, motorists have good allies. The question of the diverting of part of the Road Fund to purposes other than those for which it was established has been considered by the Law Committee of the Association, who brought it before the general body of members last Thursday. As a result, the Prime Minister and the Chancellor of the Exchequer are to be asked to receive a deputation from this influential organization, who will urge that the proposal to use the fund for other purposes (which includes the electricity scheme) should not be entertained.

Coal Exports.

There was a slight improvement in coal exports during September as compared with August, although the total has a sad appearance alongside the business done in corresponding periods of previous years. The quantity of coal of all kinds sent abroad during September was 3,902,006 tons. This compares with 5,098,406 tons in September, 1924, and 6,316,396 tons in September, 1923. The values in the three periods were: September this year, £3,650,844; 1924, £5,738,364; 1923, £7,824,126. In these figures, gas coal represented last month 514,386 tons, with a value attached of £438,676—averaging only 17s. 0·67d. per ton, whereas in August the average was 18s. The export of gas coal in September, 1924, was 696,770 tons; the value being £749,663. In September, 1923, the gas coal shipped amounted to 738,240 tons, having a value of £885,036. Taking the nine months of the year, the exports of coal of all kinds totalled to 37,464,815 tons (value, £38,197,224). In the corresponding period of 1924, the shipments were 46,792,096 tons (value, £55,837,606). In the same period of 1923, the quantity sent abroad was 59,472,942 tons (value, £75,395,567). The figures disclose the tremendous extent to which the coal industry has suffered in its export business; and in this gas coal has had its part, though not in proportionate degree to other classes. In the nine months of this year, the amount of business in gas coal abroad has been 5,008,536 tons, as compared with 6,424,356 tons in the corresponding period of 1924, and 6,050,160 tons in that of 1923. The values of the last three mentioned quantities were: 1925, £4,804,847; 1924, £7,453,056; 1923, £8,453,494.

Gas Coke Shipments.

In quantity, coke exports showed extraordinarily badly during September; the sales abroad only amounting to 68,115 tons, as compared with 108,307 tons in September, 1924, and 140,339 tons in September, 1923. As a matter of fact, the quantity shipped during the month was something like 30,000 tons below the shipments for the month of August. The value attached to the 68,115 tons was £66,229, which averages 19s. 5·3d., as compared with 18s. 10·5d. in August. Thus, in the matter of value, there was a little improvement. The value of the exports of gas coke in September, 1924, was £190,381, and for September, 1923, £241,870. In the nine months, the quantity sent abroad was 436,142 tons, of a value of £520,000. In the nine months ended September, 1924, the exports amounted to 721,840 tons, of a value of £1,264,147. In the same period of 1923, the shipments totalled to 834,305 tons, carrying a value of £1,319,035.

Sulphate of Ammonia Exports.

There was a little augmentation of the shipments of sulphate of ammonia during September, as contrasted with August. During the month 21,254 tons were exported, as against 19,982 tons in August. In September last year, the quantity was 23,225 tons. Taking the whole of the nine months, 197,298 tons were sent overseas, as compared with 201,017 tons in the corresponding period of 1924. Spain and the Canaries continue to be our best customers, and Japan comes next; but France has fallen off.

Coal Tar Products.

During September, the exports of benzole continued to fall; the returns showing that only 473 gallons were sent out of the country, as compared with 117,641 gallons in September, 1924. In the nine months of the year, the quantity has reached only 141,226 gallons, which compares with 1,287,507 gallons in the corresponding period of 1924. This indicates that the home demand can absorb all the benzole that is available. Regarding naphtha, the shipments in September amounted to 3664 gallons, as against 6862 gallons in September, 1924. The quantity shipped during the nine months of this year was 39,237 gallons, which compares with 158,152 gallons in the same period of 1924. Combining tar oil, creosote, &c., it is seen that in September 1,153,569 gallons were sent abroad, as against 2,513,000 gallons in the same month of 1924. The figures for the nine months vary to a small extent in comparison with last year. During the nine months, 31,552,010 gallons were shipped, as against 31,771,003 gallons in the corresponding period of 1924.

PERSONAL.

Mr. GARDNER PENNINGTON, who received his early training at Kendal, and has since held important posts at St. Albans and Rochester, has recently been appointed Engineer and Manager to the Sittingbourne District Gas Company.

The appointment of Distribution Superintendent to the Luton Gas Company has been given to Mr. NOEL S. SMITH, who at present occupies a similar position with the Greenock Corporation Gas Department. He has been twelve years in Greenock, mostly under Mr. George Keillor as Engineer and Manager; and during this time he has been untiring in his efforts to popularize the use of gas. He was President of the Scottish Gas Salesmen's Circle. Prior to going to Greenock, he was five years at Swadlincote, one year at Stamford, and two years at Redditch.

On completing fifty years' service with the Leamington Priors Gas Company, Mr. W. E. T. HEMS (the Secretary) has been presented with a cheque by the Directors.

Mr. PERCY DREWETT, who was Manager and Secretary of the Fareham Gas and Coke Company for 12½ years (and held the position up to the time when the concern was acquired by the Gosport District Gas Company), has been presented by the employees with a handsome oak clock, suitably inscribed. Mr. J. T. Marlow, as the oldest employee, made the presentation, and in doing so said that the subscribers desired to express their very sincere appreciation of the kindness and consideration they had always received from Mr. Drewett. Now that he had retired, they desired him to accept the small token of their esteem, and wished him and Mrs. Drewett a long life of good health and happiness. Mr. Drewett, in accepting the gift, said he greatly valued the spirit which had prompted it. He regretted severing his association with his former colleagues, from whom he had always received loyal co-operation and efficient service.

OBITUARY.

The death occurred, suddenly, on the 26th ult., in his 67th year, of Mr. DAVID J. THOMPSON, for the last seven years Chief Inspector of the meter inspection section of the Leeds Gas Department, and who had been connected with the Corporation for fifty years. Mr. Thompson was highly respected in all branches of the Gas Department.

EVENING STAR LODGE, No. 1719.

The W.M., W. Bro. Hermann L. Sheppard, presided over a well-attended meeting of the Evening Star Lodge, which was held at Freemasons' Hall, Great Queen Street, W.C., last Wednesday. He was supported by Bro. A. H. Henry, S.W., Bro. Fredk. G. Cockey, J.W., and the other officers. A cordial welcome was given to Bro. E. P. Stevenson, of Buenos Ayres, who is on a visit to England, and to W. Bro. William A. Surridge, P.M., P.A.G.D. Much pleasure was derived from a communication from Hastings, expressing the good wishes of the veteran W. Bro. T. H. Martin, P.M., P.P.G.S.B., Herts. (honorary member). Acknowledgments of the congratulations of the Lodge tendered to V.W. Sir P. Colville Smith, Grand Secretary, on the honour of Knighthood which had been conferred upon him by His Majesty the King, were reported.

A statement was presented as to the position of the Lodge with respect to the Freemasons' Hospital and Nursing Home. Arrangements were made for the appointment of a representative of the Lodge in its capacity of a Founding Lodge of the Hospital. The W.M. made appreciative reference to the invitation which the members had received from the Northern Star Lodge to participate in the celebration of its twenty-first anniversary at Manchester to-day (Nov. 4).

Mr. Leslie Walter Dunn, son of the Secretary of the Lodge (W. Bro. W. T. Dunn, P.M., L.R.), was initiated, and Bro. Wilfred B. Claridge, of Marlborough, Wilts., and Bro. James W. Swan, of Hitchin, Herts., both of whom had been initiated at previous meetings, were advanced a degree.

At the close of the Lodge dinner was served in the adjoining Connaught Rooms—W. Bro. Sheppard in the chair. Proposed by him, the Loyal Toast and that of "The Grand Master" were duly honoured. During the evening the usual toasts were submitted and honoured; Bro. L. W. Dunn giving a fitting response to the most important, while acknowledgment was made of the toast of "The Visiting Brethren" by W. Bro. E. A. Watson (Langthorne, No. 1421), W. Bro. C. Watkin Knight (Hartington, No. 1085), and Bro. P. G. Sheppard (Commemoration, No. 2663).

The toasts were interspersed with some well-rendered musical selections.

THE SHEFFIELD COKE CONFERENCE.

Under the auspices of the Chemical Engineering Group and the Yorkshire Section of the Society of Chemical Industry, the Institution of Chemical Engineers, and the Midland Institute of Mining Engineers, the discussion of the papers read in Leeds on July 16 last on smokeless fuel, together with the winning papers in the Coke Competition organized by the "GAS JOURNAL" will be resumed on Friday, Nov. 20, in the Mappin Hall of the University, Sheffield, under the Chairmanship of Sir Arthur Duckham, K.C.B. There will be two sessions, in the morning at 10 a.m., and in the afternoon at 2.30 p.m. All interested in the subject are cordially invited to attend. Advance copies of all papers can be obtained as under:

Coke papers, 1s. 3d. post free.
Leeds papers, 1s. 3d. post free.
The two combined, 2s. 6d. post free.

Cards of admission may be had on application to the Hon. Secretary, Chemical Engineering Group, No. 307, Abbey House, Westminster, London, S.W. 1.

FORTHCOMING ENGAGEMENTS.

[*Secretaries of Gas and Kindred Organizations are asked to assist in making this diary of events as complete and useful as possible by sending the earliest intimation of all meetings.*]

Nov. 5.—GAS COMPANIES' PROTECTION ASSOCIATION.—Annual general meeting at Caxton Hall, Westminster, at 3 o'clock.
Nov. 7.—NORTH OF ENGLAND GAS MANAGERS' ASSOCIATION.—Half-yearly auxiliary meeting at the Gas Office, Grainger Street, Newcastle-on-Tyne, at 2 o'clock.
Nov. 7.—SCOTTISH JUNIOR GAS ASSOCIATION (EASTERN DISTRICT).—Joint meeting with Western District, at Glasgow.
Nov. 7.—WALES AND MONMOUTHSHIRE JUNIOR GAS ASSOCIATION.—Meeting at Newport, Mon.
Nov. 10.—CENTRAL EXECUTIVE BOARD OF THE NATIONAL GAS COUNCIL.—Meeting.
Nov. 10.—FEDERATION OF GAS EMPLOYERS.—Meeting.
Nov. 11.—MANCHESTER AND DISTRICT JUNIOR GAS ASSOCIATION.—Visit to the works of Messrs. Drakes, Ltd., Halifax.
Nov. 12.—SOCIETY OF BRITISH GAS INDUSTRIES.—Autumn general meeting at the Hotel Cecil, under the presidency of the Rt. Hon. Sir Alfred Mond, Bart., M.P.
Nov. 12.—LONDON AND SOUTHERN DISTRICT JUNIOR GAS ASSOCIATION.—Visit to the Gothic Works, Edmonton, of Messrs. R. & A. Main, Ltd.
Nov. 18.—SOUTHERN ASSOCIATION.—Meeting at the Hotel Cecil, Strand, W.C. 2, at 2.15 p.m.
Nov. 20.—COKE CONFERENCE, Sheffield.
Nov. 21.—INSTITUTION OF CHEMICAL ENGINEERS.—Meeting at 8 p.m. at the Institution of Mechanical Engineers, Storey's Gate, S.W. Discussion to be opened by the Hon. H. Fletcher Moulton, M.C., on "Scientific Research Workers and Industry."
Nov. 21.—SCOTTISH JUNIOR GAS ASSOCIATION (WESTERN DISTRICT).—Visit to Kirkintilloch Gas-Works.
Nov. 25.—EVENING STAR LODGE.—Meeting.
Nov. 26.—MIDLAND ASSOCIATION OF GAS ENGINEERS AND MANAGERS.—Autumn meeting at Birmingham.
Nov. 27.—LONDON AND SOUTHERN DISTRICT JUNIOR GAS ASSOCIATION.—Meeting at the Westminster Technical Institute.
Nov. 27.—NORTHERN STAR LODGE.—Regular meeting.
Dec. 5.—SCOTTISH JUNIOR GAS ASSOCIATION (EASTERN DISTRICT).—Visit to Alloa. Paper by Mr. W. Scott.

INSTITUTION OF GAS ENGINEERS.

Nov. 10.—4 p.m., Advisory Committee on Education.
Nov. 11.—11.30 a.m., Emergency Committee. 12.15 p.m., Benevolent Fund Committee of Management. 12.45 p.m., Finance Committee.
Nov. 25.—11 a.m., Institution's session at the Public Works, Roads, and Transport Congress, Royal Agricultural Hall, Islington.
Dec. 2.—Official visit to the Shipping Engineering and Machinery Exhibition at Olympia.
Dec. 8.—4 p.m., Advisory Committee on Education.
Dec. 9.—11.30 a.m., Emergency. 12.30 p.m., Finance.

Will.—Mr. Robert Henry Holland, formerly Manager of the Swinton and Mexborough Gas Company, who died at the age of 80, left estate of the gross value of £14,058, with net personalty £9674.

North of England Gas Managers' Association.—As announced in our "Forthcoming Engagements," the half-yearly auxiliary meeting will be held on Nov. 7 at Newcastle-on-Tyne. The chair will be taken at 2 o'clock by Dr. Geoffrey Weyman, and there will be papers by Dr. E. W. Smith, F.I.C., and Mr. T. Campbell Finlayson, M.Sc., on "Developments in the Treatment of Crude Gas;" and by Mr. A. D. Cummings, B.Sc., on "The Mechanical Condition of Sulphate of Ammonia."

ELECTRICITY SUPPLY MEMORANDA.

THE Government appear to be incapable of appreciating the view of the gas industry towards their proposals to give preferential assistance to the electricity industry to enable it (so they think) to develop and confer untold benefit upon the country. That this obtuseness exists we gather from the nature of certain remarks made by the Minister of Transport (Col. Wilfrid Ashley) at the annual dinner of the Electrical Power Engineers' Association. It is clear the Government only regard the matter from one aspect, and not from all. There are three questions which we should like to be considered and answered. The first is, What are the proofs in the hands of the Government that industry and unemployment will be appreciably benefited by their plans? The second is, Is the electricity industry in such a parlous position that it needs the special aid of the Government? The third is, Is it fair to an old-established industry such as gas supply, which utilizes with much greater efficiency the coal of the country, that the Government should boost a competing industry to its disadvantage? There has not been a shred of evidence that there is any need whatever for a Government electricity scheme, or that, if the Government allowed the industry to develop normally, there would be any diminution in the pace of the progress of electricity utilization. Col. Ashley predicts that there will be an enormous increase in the use of electricity during the next few years. Then why the necessity for any intervention by the Government? We see no reason other than the political one, that they desire to impress upon the country that they are doing something to help the industry and unemployment; while the experts unkindly say that it will do precious little good. The Minister of Transport added that some people seem to think that the increase in electricity would be at the expense of the rival commodity. But, in his opinion, there is room for many forms of heat and power; and history shows that the gas and electricity industries have progressed together. That is precisely what the gas industry now wants—that the two industries should continue to progress together without Government interference on behalf of one. Whether or not the intervention will actually be to the advantage of the electricity industry and the country is not the question at the moment. The intention is that it shall be.

Leave Them Alone.

On the same occasion, the new President of the Institution of Electrical Engineers (Mr. R. A. Chattock, Chief Engineer of the Birmingham Corporation Electricity Department) showed that he is among those technical and industrial observers who believe there is advantage to be gained from the greater co-operation of the gas and electricity industries. According to the reports of his speech, Mr. Chattock spoke of the "great development" there has been in the electricity industry during the past forty years; and he stated that the rate of progress now is greater than it was ten or fifteen years ago. He might, on this ground, have invited Col. Ashley to suggest to the Government that the industry should be left to proceed as it is doing. But he went on to say that development had been uphill work for a young industry in competition with big vested interests. We have been trying to reconcile the "uphill work" with the "big development," but cannot do so. The fact is that during the whole time that electricity has been in competition with gas, business in the latter has also developed; and, as with electricity so with gas, the rate of progress is greater now than before. Mr. Chattock agrees with the Minister of Transport that there is room for both gas and electricity. That has never been denied from our side. He also holds out the hand of friendship to the gas industry. "There are signs," he said, "that gas and electricity are becoming more friendly; and this will afford a solution to the problem"—the "problem" apparently being the better utilization of coal. We have seen this friendliness in connection with co-operation in various defensive measures in parliamentary matters—particularly in relation to interference with the rights of public utility property in the subsoil of roads—and, to mutual advantage, in the growing patronage by electricity undertakings of coke and coke breeze for use with the inferior and cheaper grades of coal or slack under steam-boilers. Mr. Chattock's advice to the power engineers was that they should do all they could to work in this regard hand in hand with the gas industry. In this way, he said, more perfect combustion of fuel could be achieved; and the electricity industry would profit by the large experience of gas engineers. Years have passed since this form of co-operation was advocated by the gas industry; it is comparatively recently that real development in it has taken place. The advantages to electricity undertakings of being able to use cheap fuel from the coal mines, and ensuring by the use of coke a good combustible bed under the boilers, should carry far the business relations between the two industries.

Rapprochement.

Very appositely the opening conferences of the Electrical Development Association were allocated to lighting questions. At the first, Mr. W. E. Bush, who is allied with the Electric Lamp Manufacturers' Association, treated of the subject of "Selling Better Lighting to Shopkeepers." Judging from what he had to say, the electricity supply industry ought to be downright ashamed of itself for participating in the deplorable spectacle of bad shop lighting which is current to-day, after all the preaching and teaching there has been regarding the principles that should govern the lighting of such premises—in the interests of tradesmen, their customers, and the public. A few data from Mr. Bush's paper will illustrate the appalling conditions which he alleges exist. He states that a survey of retail shops recently undertaken indicates that two-thirds of the shop windows in the country are using 1925 lamps with equipment designed a quarter of a century ago. This is a considerable disadvantage to both the electrical industry and shopkeepers. He charges shopkeepers with not understanding the fundamentals of good lighting, which ignorance has resulted in the primitive displays forming the bulk of electric lighting installations. The shopkeeper has merely substituted new lamps for old, with the result that a walk down any shopping thoroughfare to-day is almost certain to cause a severe headache due to the strain of encountering thousands of blazing lamps in the shop windows. Mr. Bush being an expert on these subjects, his allegations must be accepted. His view is that shopkeepers have been competing with each other to purchase the most glare; and, in doing this, they have inflicted considerable damage on the electricity supply industry by exhibiting to "millions" of prospective consumers the crudest examples of electric service. There is a tendency in electrical circles to underrate the importance of this subject of glare; and, Mr. Bush declares, it is usually considered by salesmen to be a highly technical matter with which they have little concern. To their critic, however, it is one of the most vital commercial subjects with which they have to deal. Besides the serious loss of custom through glare, there is the additional loss involved in sheer waste of electrical energy from the bare lamp—the light, instead of being under control and directed on to the goods, is broadcast in all directions, so that well over half of it shoots straight through the window on to the pavement, instead of performing its proper duty. We do not know how the calculation has been made, but Mr. Bush estimates that through this some 19 million candle power is lost in this country—simply because correct equipment is not employed. Then it is alleged that, measured by good modern practice, only 17 p.ct. of the shop windows in Great Britain can be classed as well lighted. It is also asserted that the lighting of shop interiors is little better than the windows. A few examples were quoted from the survey previously mentioned. The use of obsolete lighting is found in 51 p.ct. of drapers' shops, in 81 p.ct. of grocers', in 85 p.ct. of confectioners', in 66 p.ct. of boot shops, and, judging from a diagram that is presented in the paper, many other forms of shops (40 to 80 p.ct. of their class) can be indicted for having obsolete lighting. It is found that the lighting of counters and goods is so indifferent that customers have often to carry the articles to the nearest lamp; and even then examination is not an easy matter owing to glare or inadequate intensity. It would, therefore, appear from what Mr. Bush has to say that there is a vast amount of work to be done in clearing away objectionable and old-fashioned lighting, and replacing it by that which is approved. It should be impressed upon every tradesman that good lighting is good advertising.

Better Shop Lighting.

Electrical exhibitions are being held up and down the country, and naturally from them business results for the electricity undertakings concerned. But Alderman Phillips, of Salford, has an impression that they also do good for the gas undertakings. People are not so intrigued by electricity that they altogether ignore comparison on an economic basis, and the result is that they are directed to gas. Or if the exhibition results in the placing of a few electric cookers or heaters, the results are frequently such that their dissemination does not help the business in these lines to make notable flights in adoption. Speaking at the annual meeting of the British Commercial Gas Association, Alderman Phillips told how there has recently been an electrical exhibition at Salford; and there was an immediate increase in the demand for gas appliances! He does not know whether this was a result of the electrical exhibition; but the fact of an immediate increase in the demand for gas appliances cannot be disputed. The Alderman has splendid opportunities for examining the relative positions of gas and electricity through the ownership of both undertakings by the Corporation. His experience is that, when people have electric cookers installed, they often wish to return them pretty soon, and then the demand for gas cookers increases. Information as to similar experiences has reached us from many places. We have known of cities and towns where the electrical salesmen are "live wires," and when they have succeeded in installing a hundred or so electric cookers, they have rushed into print with the glad tidings. An increase goes on for a few months, elation grows, and then—silence. The tide has begun to ebb. First gas-boiling rings are fixed to aid the electric cookers in their culinary duties. Many cases have been reported where later the electric cooker has become derelict, or, if on hire, has been returned, and the gas cooker has been re-established. This is the sort of thing

Electrical Exhibitions Boost Gas.

that yields an immense amount of good for the gas industry. However, there is one thing the gas industry must do, and that is to modernize existing cookers as they are brought in for renovation, so as to provide the means for increasing the efficiency of both the hotplate and the oven.

Bases of Comparison. There was occasion recently to criticize the absurd fundamentals for comparison adopted by the writer of "Cooking and Heating Notes" in the "Electrical Times." Everybody—apparently the writer of those "Notes" excepted—knows full well that, unless bases of comparison correspond, the result is vitiated. To obtain real comparison as to costs, the conditions must be exactly similar; and what can be done under those conditions with a gas and an electric cooker can be repeated anywhere, if people will only take the necessary trouble. The condition of misuse is as applicable to one cooker as to the other. That, too, cannot be denied. The simplicity of structure of the gas cooker enables it to be used with uniform efficiency at all times, while the unreliability of the electric cooker is becoming daily more notorious. The writer of "Cooking and Heating Notes" has made an assertion which we challenge him to prove by tests conducted under uniform conditions, and with representatives of the gas and electrical interests present. He categorically asserts that "the cost of cooking electrically is no more expensive than using gas where the cost of a therm supplied electrically is five times that of a gas therm." That is a very rash statement. He will admit that 29 KW.-H. have to be expended to obtain 100,000 B.Th.U.; therefore assuming the gas therm costs 9d., 3s. 9d. can be spent on electrical energy to realize 100,000 B.Th.U., and equality in actual work will be achieved by it against an expenditure of 500,000 B.Th.U. made available by 3s. 9d. worth of gas. That is the contention; and the man who so lightly makes it has riveted himself to a statement which we defy him to prove by a working test comparable in every respect, and which can be carried out in any household where both means of cooking exist. Does he appreciate that his statement means that, if a boiling element on an electric hotplate, when new, will give an efficiency of 45 p.ct., a boiling ring on a gas cooker will only give 9 p.ct. efficiency? If he believes that, then out of politeness we refrain from applying what we think would be a suitable description of him. We invite him to come forward and prove his publicly-made statement in public, on the bases of equality of work. He says it is important to remember that what he asserts—viz., that the cost of cooking electrically is no more expensive than using gas when the cost of a therm supplied electrically is five times that of a gas therm—represents the results in practical service, and not the most plausible arguments as to why it cannot be so can alter the fact. Then leave argument, and let the writer come along and put the matter to practical test, which is the only fair and reliable means of determination. If he cannot guarantee that there is uniformity of service, then there is a flaw in his argument and statement. A heat unit is a heat unit; no one can get more from it than there is in it. Its performance in any operation is an effect of the efficiency of its application; and the efficiency with which it is applied produces the expenditure of heat, and the expenditure of heat the money cost. The personal factor cannot be omitted in utilizing comparative figures produced under the variable methods of households; there must be consistency of conditions—a definite amount of work must be done—to give actually relative data. That no one can deny. We see that this electrical dispenser of vague comparisons relies much on the economy which is practised with electricity because people think it is dear, and the waste that is allowed with gas because people think it is cheap. Such piffle does not afford a true comparison.

"Safety" Items. The people in Denmark Street, Holborn, must have had somewhat of a shock last Saturday week, if the newspaper reports have not inflated the occurrence. It is stated that an explosion occurred in the electric cable conduits under the pavement; and "with a great roar the mains burst," throwing the inspection cover across the road, and displacing some flagstones. Flames shot out of the conduits. Almost immediately the explosion was followed by another a few yards farther down the street; but the damage in this case was not so great. Recently an electrician employed at the power station of the Aitken Pit, Kelty, received a fatal shock by coming into contact with a live wire. A man employed as a coal cutter at the Bardykes Colliery, Cambuslang, has lately lost his life as the result of an electric shock. An electric fitter has been killed, through receiving a shock, at a sub-station at Simonstone, belonging to the Lancashire Electric Power Company.

A paper on "Stone Dust as a Preventive of Coal Dust Explosions; Comparative Tests," by Mr. G. S. Rice and Prof. R. V. Wheeler (Safety in Mines Research Board Paper No. 13, H.M. Stationery Office, Adastral House, Kingsway, London, price 3d. net), has just been published. This paper is an outcome of the arrangement for co-operative research made between the Safety in Mines Research Board and the United States Bureau of Mines.

BRITISH TAR.

One of the Nation's Important Assets.

The suggestion which has been put forward that the Government should spend money on research with a view to eliminating the inherent defect of bitumen as a road material—that of slipperiness in use—does seem absurd when there is a home-produced material—tar—which does not possess this defect, and the increased employment of which, moreover, would help to increase the nation's prosperity at a critical period, and tend to decrease unemployment. This, among other interesting points, was discussed on Wednesday last, Oct. 28, when, at the invitation of the British Road Tar Association, members of the Press visited the Road Tar Exhibit at Wembley. This exhibit has been fully described in the "JOURNAL;" but it may be mentioned that recently the roadway forming part of the exhibit was relaid. In its new form the road is a remarkably good example of what can be done when suitable tar is used and the tar macadam properly made and laid.

CHARACTERISTICS OF TAR AS A ROAD-MAKING MATERIAL.

British coal tar can justly claim to have been the earliest of modern road-surfacing materials. Thousands of miles of road exist throughout the length and breadth of the land which many years ago were made with tar macadam, or surfaced with tar, and which continue to give complete satisfaction. To a specification (this was given in the "JOURNAL" for Sept. 16, p. 663) British tar has all the characteristics essential for the construction of road surfaces capable of withstanding for long periods the stress and strain of modern traffic, and is more economical in use than any other form of road-making material. To secure immunity from the appalling accidents which are an almost daily occurrence on the highly-polished surface of the new arterial roads, it is essential to secure adhesion between the tyre and the road. Tar, in combination with approved mineral aggregates, in the form of tar macadam or as a top surface dressing, not only gives sufficient wheel adhesion to prevent skidding, but retains it whether the road be wet or dry. With an adequate amount of suitable stone chippings as a top-dressing material, tar forms a protective surface against external influences and adds enormously to the life of the road by amalgamation with the existing surface.

Great Britain is spending £40,000,000 a year on road construction and maintenance. British materials—at least the equal of any imported substitutes—are immediately available for all requirements. There can be no doubt whatever that the extended use of British tar for British roads will greatly benefit the important British industries that produce it, and thus materially assist the gas, coal, and steel industries to reduce the price of their commodities.

Prior to the inspection of the exhibit, a luncheon was held at the Wembley Garden Club. Mr. H. C. Head, the Chairman of the Joint Committee of the British Road Tar Association, and Engineer, General Manager, and Secretary of the Winchester Water and Gas Company, presided; and among others prominent in the gas and the coke-oven industries were Lord Gainford (Chairman of the Coke-Oven and Bye-Products Association), Mr. S. Henshaw, Mr. J. H. Ellis (Chairman of the Plymouth and Stonehouse Gas Light and Coke Company), and Mr. H. E. Bloor (Engineer and Manager of the York Gas Company).

After the Loyal Toast,

The CHAIRMAN, mentioning that the British Road Tar Association was representative of the gas and coke oven industries, said how sorry they were that Mr. D. Milne Watson was unable to be with them, owing to his attendance at a Government Inquiry. Mr. Head then read the following letter which he had received from Mr. Milne Watson:

> I am very sorry that I am prevented at the last moment from attending the luncheon which is being given by the British Road Tar Association at Wembley on Wednesday, Oct. 28. I have been appointed on the Government Committee of Inquiry into the Public System of Education of England and Wales, relating to the requirements of Trade and Industry, with particular reference to the adequacy of the arrangements for enabling young persons to enter into and retain suitable employment; and this Committee is holding its first sitting on Wednesday next, at 2.30 p.m. I have endeavoured to get the time of this Committee altered, to enable me to come to Wembley, but this has been found impracticable.
>
> I am very glad that the Association has taken this opportunity of inviting the Press to pay a visit of inspection to the British Road Tar Stand, as I think that it is most important at the present time, when large schemes of road construction are under consideration, that publicity should be given to the fact that British-produced tar can be used for the making-up and surfacing of roads in quite as satisfactory a manner as with other material, and at a cheaper rate. There is also the important consideration to the motor industry that, when a road is dressed with tar, the slippery surface, which is such a bane to motorists, is almost entirely overcome.
>
> The wider aspect of the question, moreover, must not be overlooked—that it is the duty of every citizen to do whatever he can to help to stimulate trade in this country. One simple way to

assist in this direction is surely to buy British goods. The present position provides an unique opportunity for those authorities interested in road construction to see that British tar is given preference over other materials; thus restricting the imports into this country, and reducing unemployment. It seems to me that the British Road Tar Association has an overwhelming case; and I feel sure that the representatives of the Press will be very interested in this national aspect of the question.

D. MILNE WATSON,
President of the National Gas Council.

Oct. 26, 1925.

Fifty or sixty years ago, said Mr. Head, tar was not valued highly. Indeed, the problem then was how to get rid of it. Times, however, had changed. Many years ago Earl Beaconsfield had suggested that the progress and prosperity of a country could be measured by the amount of sulphuric acid used. He, the speaker, would put forward the view that the prosperity of this country depended in no small measure on its employment of "tar." Tar products, it must be remembered, had a marked effect on the price at which gas could be sold; and it was highly important that the charges for gas should be reduced as much as possible. And then, in the steel industry, it was a fact that every £1 per ton gained by the sale of tar resulted in a reduction of 6s. per ton in the price of steel. Thus the getting or losing of a foreign contract for steelwork might depend on the price obtained for tar. The industrial situation—particularly round the north-east ports—was pitiable; and it was up to everyone to help the coal and the iron and steel trades. By purchasing home-produced tar, not only could this be done, but the condition of the roads could be improved at the same time. A great deal had been heard recently about cheap power. Well, this country was not a water-power country, and by the very nature of things could never hope to be one. Its whole commercial greatness was built-up on its coalfields. Coal formed the basis of all British industries; and they must look to the bye-products to reduce its net cost. The Government were making special research into the economical uses of coal; and if they succeeded in finding processes in which more coal would be treated before it was burned in open fireplaces, the money would be well spent. All interested in home products should see that the market was not taken by the foreigner. A fair amount of tar was used for road-making purposes; but the Road Tar Association wanted more sold in an expanding market. This problem of bye-products, suggested Mr. Head, was of far greater importance than that of the much-discussed idea of super-power stations—the amalgamation of existing power stations. Electricity, it must be remembered, was merely a means of conveying power (in England the power contained in coal), as the railways were a means of conveying goods and passengers. And what great benefits had accrued from the amalgamation of the railways? Reverting to the subject of tar, the question which naturally arose was whether the product which they were offering for road making was the best, or at any rate as good as any other material that was being marketed. He would say that tar was not only as good as any other substitute, but possessed definite points in its favour; a marked advantage being that roads made of tar were not so slippery as those made by a foreign product.

Lord GAINFORD, speaking as Chairman of the Coke Oven and Bye-Products Association, said that the coke industry of this country was labouring under difficult conditions. The prices obtained for bye-products were extremely low in proportion to the capital invested in bye-product plant. All they asked for was fair play. Bitumen had been unduly advanced by large expenditure in its interests. It had been urged that, while bitumen washings did not influence fish life, the washings from tarred roads had a bad effect. Well, the only times when there was any likelihood of danger from roads made of tar in fishing areas were when the roads were first constructed, and when they were being broken-up. In his opinion, roads made of a mixture of tar and a little bitumen were better than those made of bitumen alone. In the latter case the safety of the public was imperilled.

Mr. SHRAPNELL-SMITH, representing the motor industry, remarked that great stress was laid on the effect of tar on fish life. This point had been magnified out of all proportion, when it was considered that only 4 p.ct. of the roads in this country touched the fishing interests. The damage to fish was due to the presence of phenols and cresols in tar; and these compounds could be fixed by the addition of a small quantity of bitumen. He had been perturbed by the large number of accidents on newly-made roads. He would say that in his 27 years' motoring experience he had never had a skid on tarred roads; but he could not say the same about other roads. The question of raising the standard of rural roads was one of increasing importance; and rural authorities were making heavy demands against the Road Board Fund. In his opinion, the use of tar, either as a top dressing or in the form of tar macadam, offered the best solution to the problem.

Following the luncheon, inspection was made of the Road Tar Exhibit. The success which has attended this exhibit is reflected in the interest shown by both road makers and road users in the employment of tar for road-construction work. Doubtless a more widespread understanding of tar and tar macadam, and of our national resources for their production—a production which will more than meet the needs of the road-construction schemes of this country—would lead to its greatly extended use for this purpose.

It is interesting to note that the British Road Tar Association will be exhibiting at the Public Works, Roads, and Transport Congress and Exhibition, to be held in the Royal Agricultural Hall, Islington, from Nov. 19 to 26. The exhibit will be found in the Gilbey Hall (Stand No. 118), and will take the form of an information bureau.

PROBLEM OF THE THICK-WALLED TANK.

By A. GADD.

In his excellent treatise on "Modern Gas-Works Practice," Mr. Alwyne Meade makes the following remarks (pp. 674, 675, Second Edition):

> There is no doubt that in the design of a masonry tank some sound theoretical treatment would prove of immense value; but at present there is no such treatment at our disposal. . . . It must be realized that the brick tank of a gasholder is not subjected to a simple bending moment, as in the case of an ordinary retaining wall . . . and instead of the wall tending to tilt over from the base, the whole undergoes in almost all cases slight circumferential stretching, while there is also a strain in the vertical direction.

The principles governing the distribution of stresses throughout the thickness of a theoretically perfect cylinder wall do not appear to have been applied to the problem named in the manner hereinafter referred to. Those principles are based upon the natural assumption that each ring of the cylinder wall must withstand the whole of the radial pressures upon it, whether those pressures be internal, external, or both. Given a thick-walled tank, perfectly homogeneous in character, and capable of transmitting forces impressed upon it in an uninterrupted manner, then the distribution of stresses throughout the thickness of the wall, for a given internal or external radial pressure, can be definitely ascertained.

Fig. 1 shows a small portion only of an assumed perfect tank wall in plan, in which p represents an *internal* radial pressure per square inch, due to weight of water within the tank, and the variably distributed tangential tensions T thereby produced along the radius concerned are merely roughly indicated. In reality, the changes in the values of the tensions referred to take place in a continuous manner, from point to point, across the width of the wall, and not intermittently. It will be noticed that the maximum tension per square inch occurs at the inner face of the wall, and the tensions gradually decrease in value towards the outer face, at which the tension is, however, greater than zero. In addition, the pressure p is transmitted radially in continuation thereof through the substance of the wall, but in a decreasing manner, so that, according to the theory, such radial pressure becomes *nil* at the outer face of the wall. As p is therefore the maximum value of this particular and reducing radial pressure, and as, in the case of gasholder tanks, p is always well below the safe crushing stress of the substance forming the wall, this reducing radial pressure need not, for the moment, enter into consideration.

The general equation which, by its solution, enables the value of the tension at any one point in fig. 1 to be ascertained is given below. In this r represents the internal radius of the theoretical tank, R the external radius, and r the radius to the point desired, all at the level of the pressure p taken. That is to say:

$$T = p.\frac{r^2}{R^2 - r^2}\cdot\left(\frac{R^2 + r^2}{r^2}\right)$$

In the above equation, r is the variable quantity, so that by integration the sum of the tensions across the width of the wall in fig. 1 can be ascertained.

The general expression for this sum comes out as:

$$p.\frac{r^2}{R^2 - r^2}\cdot\left(-\frac{R^2}{r} + r\right)$$

the definite expression for which, between the limits R and r, is:

$$p.\frac{r^2}{R^2 - r^2}\cdot\left(\frac{R^2 - r^2}{r}\right), \text{ or simply } p.r.$$

But this last value is exactly the expression for the total tangential bursting pressure, per square inch, at the extreme of a diameter of a thin steel-plate tank, which proves, as might be anticipated, that for tanks of the same internal dimensions and pressure per square inch, the tensions produced at the thick-walled tank are merely spread over a larger area, but, of course, in the variable manner indicated; or the *total* tensions, for both kinds of tanks under the similar conditions named, are alike. In practice, as is well known, the total tensions for the case of the steel tank are, as a matter of convenience, asumed to be uniformly, and not variably, distributed over the available area of plate section.

Fig. 2 is a similar view to fig. 1; but in this case the radial pressure per square inch, called P, is assumed to be wholly

external. This may be compared to a tank which is empty and subjected to the external pressure of a backing. The variably distributed tangential compressive forces C will be obvious from the figure; and it will again be noted that the maximum force exists at the inner face of the tank wall. Radial pressures in line with P through the thickness of the wall also exist, having a maximum value of P at the outer face, and vanishing to nothing at the inner face.

The value of any one crushing force C in fig. 2 in the width of the perfect wall is given by the following expression (P being assumed to act at the outer face as stated, and being the applied pressure per square inch at the level taken, and R, r, and r having the same meanings as before):

$$C = P.\frac{R^2}{R^2 - r^2}\cdot\left(\frac{r^2 + r^2}{r^2}\right)$$

By a similar process of integration already applied to the expression for fig. 1, the sum of the crushing stresses C across the width of the wall comes out as P.R. This is only what would be expected, since the static pressure upon a body of whatever shape, submerged in a liquid or pressure-imparting substance, is determined by the over-all dimensions of the body perpendicular to the pressure, and not by the shape of the body so submerged.

Comparing fig. 1 with fig. 2, it is very evident that if P could be applied to produce crushing stresses at least equal to the tensile stresses involved, at every point throughout the wall thickness, tension in the wall would be reduced to nothing. But, of course, in practice the wall will allow of P having a greater value for the purpose stated, since the wall can be relied upon to resist crushing forces within limits. Indeed, it will always be found that, where P is greater than p (and it generally is),

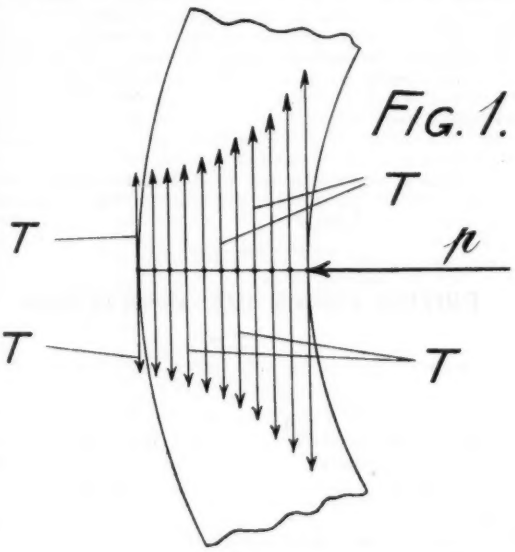


FIG. 1.

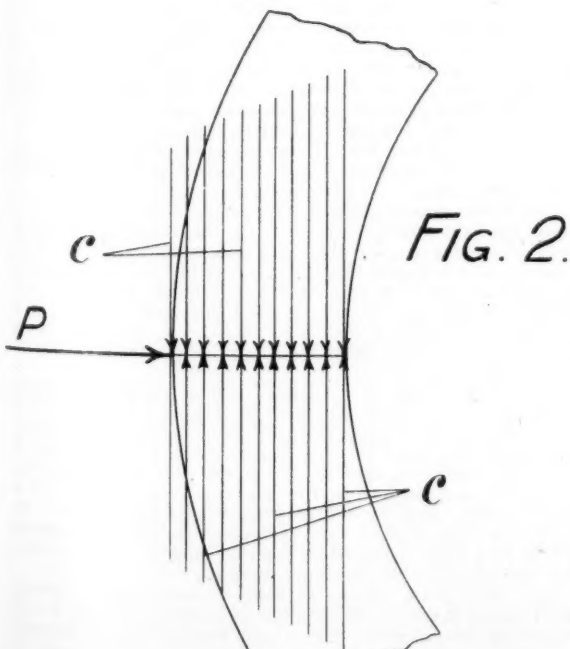


FIG. 2.

the wall of the kind assumed—*i.e.*, subjected to both internal and external radial pressures—is also subjected to an excess pressure C at each point, or greater than T at the same point; and the problem is not so much to prevent the tank bursting under water pressure, but to prevent P resulting in values of C which will crush the tank inwards.

Coming, therefore, to tanks of the kind in question, and provided with comparatively thick walls, suggestive applications of the theory herein introduced are submitted.

MASONRY TANK (WITH PUDDLE BACKING)

Whatever the nature of bonding employed, the cement or like connections between the bricks forming the wall cannot be considered integral with the bricks, and therefore throughout any one of the concentric rings of brickwork at a given level stresses cannot be said to be transmitted uninterruptedly throughout the circle considered; but as the cement connections may be considered very thin compared with a tank of ordinary dimensions, the irregularity in this respect may probably be ignored as being of no particular moment. That is to say, it may perhaps be assumed that, however the tensions and compressions in each ring of bricks may be distributed across the same to an adjacent ring, that distribution is fairly continuous around the circle of the ring.

Coming now to the distribution of stresses across the thickness of any one ring of brickwork, a doubt as to the manner in which a brick is capable of transmitting forces impressed upon it arises from the fact that even the best-formed brick is very far from being perfectly homogeneous, and it possesses a porosity of no mean extent. In whatever manner the deviation from theoretical distribution may be, the conditions are not assumed to be more important than those given in relation to figs. 1 and 2. Therefore (since in designing structures the worst conditions should be assumed) it may perhaps be taken for practical purposes that a ring of brickwork in the tank wall transmits tensions and compressions in manner similar to that already discussed. The cement joints between the rings themselves also will tend to break the continuity of transmission of forces referred to. Although the deviation from theory on this account can be shown to reduce the radial pressures even quicker than the theory demands, existence of continuity of transmission may probably be the safest to assume in actual cases, in view of doubt as to the real conditions of transmission.

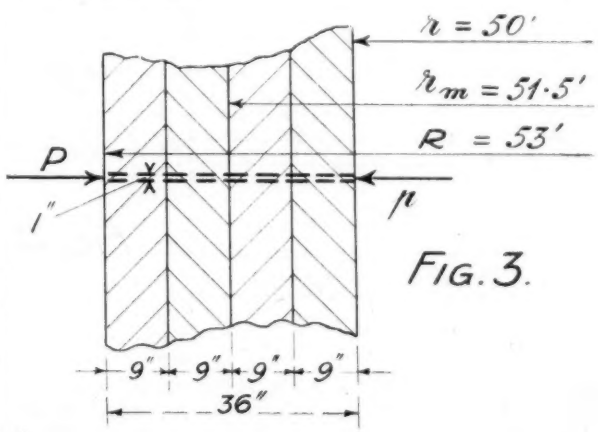


FIG. 3.

Fig. 3 shows in vertical section a portion of an assumed tank wall, the bonding employed enabling each of the four rings of which it is composed to be considered as 9 in. wide. Such as outlines of bricks, cement lining to prevent water leakage, and cement joints, are omitted. The following are the conditions taken to exist at the level adopted:

R = 53 ft. = 636 in.
r = 50 ft. = 600 in.
r_m = 51·5 ft = 618 in. (at mid-thickness).
p = 11 lbs. per sq. in.
P = 13 lbs. " " "

Using the tensional formula given relatively to fig. 1, and making r consecutively the values of r, r_m, and R, the tensions at the inner face, mid-thickness, and outer face are as follows:

At inner face, T = 187 lbs. per sq. in.
At mid-thickness, T = 181 " " " "
At outer face, T = 176 " " " "

If these tensions be set-up as ordinates along the horizontal equal in length to the thickness or width, 36 in. of wall, it will be found that not only is the line through the extremes of the ordinates practically a straight one, but that line is inclined to the horizontal to a very small extent. This goes to show that, with cylinders of the size of gasholder tanks, the tensions are not very far from being equally distributed after the manner assumed in the case of steel tanks. Therefore, in order to arrive at an average value of T, it is only necessary,

practically speaking, to divide the total tensions by the area over which they are distributed. This area is indicated by broken lines, in rectangular form, in fig. 3; the value being 1 in. x 36 in. = 36 sq. in. In this way, average value of

$$T = \frac{p.r}{\text{area}} = \frac{11 \times 600 \text{ in.}}{36 \text{ sq. in.}} = 183 \text{ lbs. per sq. in.}$$

(compare with above results).

Taking into account the added effect of external pressure P, and using the compression formula herein for finding values of C, we get:

Tank empty: At inner face, C = 234 lbs. per sq. in.
At mid-thickness, C = 222 „ „ „ „
At outer face, C = 210 „ „ „ „

Tank full (giving p = 11 lbs. per sq. in.):
At inner face, C − T = 234 − 187 = 47 lbs. per sq in.
At mid-thickness, C − T = 222 − 181 = 41 „ „ „ „
At outer face, C − T = 210 − 176 = 34 „ „ „ „

But the average difference could have been attained at once by the following:

$$\text{Average resulting compressive force} = \frac{13 \text{ lbs.} \times 636 \text{ in.} - 11 \text{ lbs.} \times 600 \text{ in.}}{36 \text{ sq. in.}} = 46 \text{ lbs. per sq in.}$$

It may be objected that, having regard to the known weight of puddle backing producing pressure P (horizontal), the value of 13 lbs. per sq. in. is rather low. This question of pressure due to puddle, properly punned, is one difficult to settle; for although the vertical pressure due to its weight follows the same law as that of water, as to being accumulative, and although the horizontal component of that vertical pressure follows the usual law as to earth pressures, depending upon the angle of repose of the puddle, it is this very angle of repose which is doubtful. Fairly recent investigations have shown that, where there are large masses of material involved, the angle of repose is not constant, or it is different near the surface compared with what it is at a greater depth. There is room here for much further investigation; but it is very evident that the horizontal component of the puddle weight cannot be very great, or else many tanks would be in danger of being crushed. Of course, this crushing tendency may be somewhat resisted by the shear stresses in the various layers of wall substance; but as the change of stress between adjacent layers is very gradual, it may be the wisest to ignore the possible resistance last referred to.

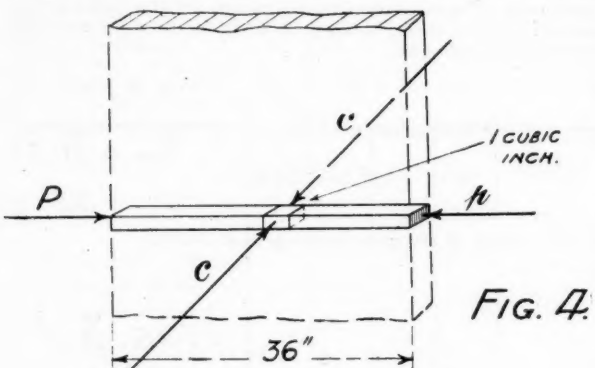


FIG. 4.

VERTICAL STRAIN.

The existence of vertical strain within the wall of a tank of the type under discussion is undoubtedly a fact. Just as a stretched rubber ring of originally circular section will lose in a diameter, so will a ring of substance which is compressed in the plane of the circle gain in the diametrical dimension perpendicular to the plane. The chief difficulty in the present case is the want of knowledge of the ratio of stress to strain for brickwork. In re-inforcement work, the corresponding ratio for concrete is usually taken at an average value of one-fifteenth that of steel. If brickwork had a similar ratio, or similar linear modulus of elasticity, this would be somewhere in the region of 800 tons per sq. in., but there is a real doubt in the matter, having regard to the low crushing stress of brickwork.

Considering a portion of a vertical strip of the tank wall, fig. 4 indicates such a strip 1 in. thick and 36 in. wide; the latter being the wall thickness. It is evident that, as all the like strips forming the whole circular wall are under the same conditions as the one indicated, the vertical strain of the latter will give the vertical strain of the whole wall.

At the level of p and P already referred to, a strip of wall 1 sq. in. in section and 36 in. long is indicated; and this strip is subjected to end pressures p and P aforesaid, and crushing pressures at right angles to the former forces. The average value of a pair of these on 1 cub. in. is indicated at C, C; the one being the reaction to the other. These average forces C are assumed to act upon a cubic inch of material of the strip shown; and if the vertical strain of such cubic inch be ascertained, as well as the similar vertical strains of all the cubic inches above and below it, from top to bottom of the tank, the sum of these will give the total strain desired.

For convenience of explanation (and not suggestive of the shortest manner of attempting the solution), the vertical strain of the cubic inch referred to in fig. 4 may be derived approximately by considering that the forces P and p, being small compared with the average crushing force C, can be ignored, although the principal stresses really involve P and p. Then the stress equal to the average value C appears in the ratio $\frac{\text{stress}}{\text{linear modulus}}$ = strain in the plane of C; and if, according to Poisson and Cauchy, the vertical strain is one-quarter of this (although this value, in the light of more recent investigation, does not appear to be constant for all substances in theoretically perfect condition), the desired result for one of the cubic inches in the strip of fig. 4 may be attained. The sum of such-like strains is approximately the ratio of actual extension to original depth of tank before the stresses were generated. Of course, the relationship between the two strains mentioned assumes a substance which possesses similar properties in every direction, or one which is isotropic; but for the purpose in view an approximation suffices.

That the crushing tendency results in vertical strain or lengthening of the tank is somewhat borne out by the fact that, in re-inforced work with concrete tanks, vertical rods or bars as well as circumferential ones are embedded. The circumferential bars operate, by their resistance to tension, to provide the equivalent of forces P already discussed, and the vertical bars are put in tension by the resistance they offer to the vertical strain referred to. But the problem of re-inforced tanks offers further peculiarities for consideration, and is a subject in itself.

BRITISH JUNIOR GAS ASSOCIATIONS.

The Annual Meeting of the Joint Council of the British Junior Gas Associations was held on Oct. 8 at Sheffield. In addition to representatives from each of the affiliated Associations, Mr. J. Bridge (Elland) and Mr. W. J. Pickering (Birmingham), who represent the Junior Associations on the Advisory Committee of the Gas Institution's Education Scheme, were present.

The working of the Education Scheme was fully discussed, in order that any difficulties might be brought before the Advisory Committee. It was announced that the abbreviation of the Education Scheme, as published in the "JOURNAL" for April 22, 1925, has now been reprinted; and it is hoped that this will assist in clearing up some of the difficulties which have confronted students. An appendix gives a comprehensive list of Technical Institutions in Great Britain, Northern Ireland, and the Irish Free State, at which instruction in the science subjects ancillary to Gas Engineering and Gas Supply can be obtained.

The Junior representatives have emphasized the position of those who are unable to qualify for the Institution's professional examination; and there are now available Minor Group Courses in Gas-Works Practice and Gas Supply Practice under the ægis of the City and Guilds of London Institute. Any junior who has not already received this leaflet can obtain a copy on application to the Hon. Secretary of the local Junior Association, or direct from the Organizing Secretary, Institution of Gas Engineers.

The small number of candidates sitting for the Gas Supply examination was discussed, with a view to finding out why this should be the case. The educational qualifications necessary were considered to be a heavy disadvantage to many of those at present engaged on the supply side of the industry; but recent modifications by the Advisory Committee will, it is hoped, tend to ease the difficulty (see "JOURNAL" for Oct. 28, 1925). It was thought that eventually the younger students will be in a better educational position, and so be able to take full advantage of the Education Scheme.

After three years' service as Hon. Secretary and Treasurer, Mr. Charles Roper, of Bradford, was cordially thanked for his service on resigning the office; and Mr. B. J. Bell (Cardiff) was elected in his place.

CONSERVATION DISCUSSED AT THE "B.C.G.A." MEETING.

THREE PAPERS PRESENTED TO THE PLYMOUTH CONFERENCE.

AT the session on the second day of the recent meeting of the British Commercial Gas Association in Plymouth, under the presidency of Mr. J. H. ELLIS, three papers on different aspects of conservation were submitted by gentlemen each of whom is an authority on the matter with which he dealt. The first of the papers will be found reproduced in full ; but circumstances necessitate the curtailment of the other two.

[In developing his subject, Prof. Cobb shows that the gas industry is entitled to claim that, on the basis of thermal efficiency alone, its methods of dealing with coal—"the nation's store of solar energy"—represent the highest order of achievement. The possibility of "fuel crops" is discussed, and that of peat, lignite, &c.; but the logical outcome for this country is shown to be coal carbonization. The advantages of the latter are detailed in simple but forcible fashion. In the author's opinion, a reversion to low-temperature carbonization would not be easy to justify. Mr. R. W. Ascroft deals from the horticultural and agricultural point of view, with the damage that is caused to the trees and plants throughout the country by lack of light, deposit of tarry matter on the leaves, and the pollution of the atmosphere with sulphur dioxide, due to the presence of smoke—thus showing conclusively that the subject of smoke abatement is not one which concerns the townsman only, but that it is the affair of every dweller in these islands, whether his or her chief business lies in a rural or an urban area. Dr. Veitch Clark makes a powerful appeal for a condition of affairs which will bring about an improvement in the health and general well-being of the race. The abolition of smoke from our midst would, he urges, do more for the betterment of public and individual health in our industrial centres than any other single action open to this country.]

CONSERVATION OF THE NATION'S STORE OF SOLAR ENERGY.

By Prof. JOHN W. COBB, C.B.E., B.Sc. (Livesey Professor and Pro-Vice-Chancellor of the University of Leeds).

I should like to begin by an explanation of what the title of this paper implies. The centre and source of energy for the solar system is the sun. It is steadily emitting enormous quantities of radiant energy, and, as a consequence, man has always been supplied with light in the daytime, and with heat from the sun's rays, more or less sufficient for his immediate needs according to the climate and the weather. But what has made the greatest material difference between civilized and primitive man is the extent to which the former has come to make use of the effects obtainable by burning fuel. With this resource, light and heat become immediately available and under his control, and the multitude of operations which depend upon heat for their performance. Indirectly, the generation of power passed into his hands through the same medium, particularly after the invention of the steam engine and the superseding of manual by mechanical work. In the long run these things all depend upon being able to get some portions of matter at a temperature higher than that of their surroundings, utilizing the contained energy of fuel for this purpose. It is obviously so with light and heat, and it is so with the generation of power.

STORAGE OF THE SOLAR ENERGY.

I will now deal with the special nature and reason of our dependence on fuel. The sun is emitting enormous quantities of radiant energy travelling in all directions. The earth is in the path of those radiations, but at such a distance from their centre that it can only possibly intercept about 1 part in every 2500 millions which the sun sends out. It is interesting, and good for the modesty of mankind, to speculate as to the reason for, and the ultimate fate of, the rest of the radiation; but this minute fraction of it is all that comes our way. Moreover, owing to the distance and the spreading of the radiation which has been taking place all the time, the intensity by the time the earth is reached has fallen off to such an extent that the stream of radiation is very feeble, particularly in cloudy countries. The heat of the sun's rays is, however, there for the taking, and particularly in Egypt and California some attempts have been made on quite a considerable experimental scale to generate power directly from it.

For this purpose the rays were reflected and concentrated by mirrors upon blackened tubes which formed part of a boiler of special construction, and the vapour generated in the boiler and its adjuncts was used to drive the engine. Qualitatively the experiment was quite successful. Power could be generated in that way (about 100 H.P. in one experiment), but the amount of plant that it was necessary to provide in order to get a few horse-power was very large compared with what can be done by the use of fuel. We may say that practically the position is that in temperate countries like our own the rate of supply and the density of distribution of the sun's radiation are not sufficiently great to allow of successful direct utilization; and the question at once arises how the radiant energy may be concentrated and stored. The answer is that it is done by vegetation, which in its fossilized or mummified form constitutes coal.

Vegetation always contains carbon and hydrogen, with some oxygen. When it is utilized as a fuel, it burns by combination with oxygen—the carbon to form carbon dioxide, and the hydrogen to form water vapour. This process generates heat—the heat of combustion of the fuel. If it were possible to reverse the process, eliminating oxygen and re-building the fuel, the process would absorb heat. The complete formation in the laboratory of an artificial fuel in this way from carbon dioxide and steam is exceedingly difficult, though we seem to be nearing a solution of this problem.

In the growth, however, of vegetation under the influence of the sun's rays and by the absorption of some of the energy which the rays bring, these compounds of carbon, hydrogen, and oxygen are built up in enormous quantities—fuels which by their combustion can give out heat. When, therefore, we burn wood from a tree, we are drawing upon the radiant energy which the tree has absorbed from the sun during the period of its life (say, one hundred years).

It looks at first sight as if we might arrange a system on this basis for supplying ourselves with fuel in which the energy absorbed from the sun's rays in one century was utilized to meet the fuel requirements of the next century, but there are various reasons against it. Human nature is impatient. The time is too long, and the growing power per square mile of a country like ours would be all too small, even if the ground were not wanted for other purposes. It may, however, be asked what the possibilities are of utilizing, instead of slow-growing vegetation such as trees, crops which could be obtained from the soil every year. Such as they are, we can use those crops and the energy they have absorbed from the sun in one year as fuel for the next. As a general solution of the fuel problem, particularly in a country like ours, this is hopeless for several reasons. One is that the quantities that could be raised would be inadequate in any case, another is that the ground is wanted for foodstuffs, and a third reason—and one of very great importance—is that the vegetable materials produced would as fuels be of low heating power compared with such a fuel as coal, the position of which I shall come to very soon.

FUEL CROPS.

At the same time, this idea of raising fuel in one year for consumption in the next is very fascinating, and it will undoubtedly find its special applications. It may be utilizable in the production of a fuel of special value for certain purposes; and experiments are being made in one direction to test this point. A number of vegetable substances can be readily treated and fermented for the production of alcohol. Potatoes have already been widely used for the purpose; also grain, barley, and mangolds, and, according to recent reports by Sir Frederick Nathan, who went into the matter for the Fuel Research Board, Jerusalem artichokes have been found particularly suitable. Going outside our own country, molasses, a bye-product of sugar refining, is valuable; and alcohol can also be produced from the fermented sugar formed by the treatment of wood cellulose. The starch and carbohydrates in these materials lend themselves to the production of alcohol. But the cost of production of alcohol, even under the best conditions obtainable or that one can foresee as obtainable, would be prohibitive for general fuel purposes. What is immediately in view is the production of alcohol to use instead of petrol as a motor spirit, and in many respects it would provide an excellent substitute or addition. In the United Kingdom such production does not seem economically possible, even for limited purposes, owing to the high cost of cultivation, harvesting, and manufacture, and the fact that the most suitable raw materials are also important foodstuffs; but it is likely to be produced, at any rate for the satisfaction of local demands, in other parts of the world.

Returning to our main thesis, we are faced with the position that we cannot satisfy our requirements by the direct and immediate utilization of the sun's rays, or by any known process of raising what one might term "fuel crops" which would place us in a satisfactory position as regards the balance of income and expenditure. We have been driven to look for stores of materials in the earth which represent the result of storing energy from the sun's rays throughout the past ages,

In other words, fossil vegetation in one form or another constitutes our fuel supply.

STAGES IN COAL FORMATION.

The ultimate product of the fossilizing process is coal; but a number of agencies, physical, chemical, and biological, have co-operated in bringing about the result gradually through intermediate stages. To begin with, what are the changes which take place in masses of vegetation which are rotting away in a half-submerged condition, and then in a completely submerged condition, under the combined action of water and air and micro-organisms? The nature and extent of such changes, no doubt, have varied widely according to climatic and other conditions, but their general nature can be seen and studied as occurring to-day in the peat bogs; and peat may be regarded as a first step towards the formation of coal. It can be seen very readily, however, on examining the composition of peat (to which we shall return), that this step does not take us very far. The formation of coal evidently requires other influences to be brought to bear, and what those are is suggested at once by the mode of occurrence of coal as we know it at great depths in the earth, where it has been plainly subjected to great pressure. Experiments which throw some light upon this subject were made about fifteen years ago by Bergius. He investigated the changes which could be brought about in cellulose (the typical plant constituent) and in peat by subjecting them to comparatively gentle heat, but under very high pressure. He took these materials and placed them in an apparatus which was to all intents and purposes the cylinder in which oxygen and other gases are stored and sent out. The results he obtained in this way are shown in Table I.

TABLE I.

Material.	Temperature °C.	Duration, Hours.	Analysis of Coal, P.Ct.			
			C.	O.	H.	N.
Peat, original dry substance .	..	..	52·4	41·4	5·50	0·70
,, ...	250	8	74·3	19·4	5·20	1·07
,, ...	300	8	77·0	16·9	5·00	1·07
,, ...	340	8	81·2	13·3	4·65	0·89
,, ...	340	24	84·0	10·4	4·62	0·95
,, ...	340	61	83·5	11·0	4·60	0·97
Cellulose	310	64	83·7	10·9	5·40	..
,, ...	340	8	83·1	11·7	5·20	..

It will be seen that the effect of this treatment has been to eliminate to a very considerable extent the hydrogen and oxygen, particularly the latter, from the cellulose and peat, with a corresponding concentration of the carbon. The ultimate result was a substance which in chemical composition and in some of its physical properties resembled coal. It is not suggested that the temperature to which the coal had been subjected in the process of its formation was as high as those used in this set of experiments. That is unlikely, or indeed impossible. But what is suggested is that the higher temperature used in the experiments had speeded up the chemical changes occurring, according to a well-known principle. They had made it possible to bring about in a few hours changes which at lower temperatures would have required many thousands of years. An attempt to speed up the process by simply raising the temperature without the accompanying use of very high pressures would, we know, have failed at once by bringing about more destructive chemical changes.

At this stage we may well consult Table II., which shows the composition of various fuels which can be taken as representing stages in the process of coal formation—wood, peat, lignite (or brown coal), coal, and anthracite.

TABLE II.—*Composition of Dry and Ashless Fuels.*

——	Carbon.	Hydrogen.	Oxygen (and Nitrogen).
Cellulose ($C_6H_{10}O_5$) .	44·5	6·2	49·5
Wood	50·0	6·0	44·0
Peat substance . .	50–64	4·5–6·8	28–44
Lignites	60–70	5·0	20–35
Bituminous coals . .	75–90	4·5–5·5	5·5–15·0
Anthracites. . . .	90–95	2–4	3

You will see that they all represent a gradual concentration of carbon at the expense of hydrogen and oxygen, so that we pass over from a substance such as dried wood or cellulose (a principal plant constituent) containing less than 50 p.ct. of carbon to coal containing 80 to 90 p.ct., while in anthracite the carbon is even higher. There is one feature of the change which is particularly important from the present point of view, and that is that the changes which have taken place during the transformation have resulted in the production of a substance in which heat energy is stored in a more concentrated form, the production of a higher grade and more useful fuel.

The complete combustion of 1 lb. of coal generates approximately twice the number of heat units which may be obtained from 1 lb. of cellulose or dried wood. We may briefly consider what are the possibilities of these different fuels, wood, peat, lignite, and coal.

OUR DEPENDENCE UPON COAL.

Wood can be dismissed very briefly, at any rate so far as we are concerned in this country. When completely dried, it has only about half the heating value of coal, and this value is lessened by the fact that, when freshly cut, it contains from 30 to 50 p.ct. of moisture, and even on long exposure to air drying, from 15 to 20 p.ct. This moisture, of course, uses up so much of the available heat simply for vaporizing it.

Peat is on a rather different footing; and a considerable amount of work has been done recently, particularly in Germany and Ireland, on the utilization of this fuel. It suffers from two handicaps. The peat from even well-drained bogs will contain anything from 80 to 90 p.ct. of moisture, and in any case it is a very bulky fuel. The consequence is that peat as it is cut is quite useless as a fuel. When it has been spread out and air-dried, the moisture is reduced to about 25 p.ct., and the peat has then about half the heating value of coal. It can be used, and is used, to a limited extent as a domestic fuel and for boiler firing; but too much must not be expected from peat as a source of supply. It is to be remembered that the peat deposit in a good bog 20 ft. deep is only the equivalent of a 12 or 14 in. seam of coal, and any large output involves the laying-out and development of an enormous surface of land. It has one special chemical advantage which may at times turn the scale in its favour, and that is that it contains considerable quantities of nitrogen, averaging about 2 p.ct. This nitrogen can be partially recovered in the form of ammonium sulphate, which finds a ready market as an artificial manure.

Lignite varies very much in appearance and, indeed, in composition, depending on the stage of decomposition which has been reached. Sometimes it is very obviously like wood, and at other times obviously like coal. Its use has been developed enormously in Germany during the last few years. Indeed, the output of lignite in Germany now reaches over 100 million tons a year. Extensive deposits of great thickness occur and can be worked in the open without underground mining by mechanical excavation at a very much lower cost than ordinary coal. Its heating value varies considerably, but it can be taken that it may contain from 40 to 60 p.ct. of water. It remains a very cheap source of heat units; and its conversion into a higher grade fuel by drying it, briquetting it, or even by carbonization, can be easily carried out. Unfortunately, there are no lignite deposits of any size in this country, but in the colonies—in Canada and Victoria—there are such deposits, and they are now being developed.

The net result of this rapid survey is, however, that, so far as we are concerned in this country, in the first place we are dependent upon fossil fuel, and in the second place there is only one form of the fossil fuel upon which we can draw to any great extent—and that is coal. The whole of our manufacturing activities and many amenities of life bound up with them are dependent upon coal, which is a wasting asset—one which is not being replaced to any appreciable extent.

Though the quantities of coal known to exist in this country are not likely to be exhausted for a long time at the present rate of consumption, and though the technique of mining is so far improved that deposits are now being worked which a generation ago would have been thought unworkable, there are some factors operative on the other side to be considered. In the first place, for various reasons, the cost of coal has increased, and with some of our principal manufactured products such as iron and steel, which again form the basis for the engineering industries, the actual cost of the fuel concerned in making them is a considerable proportion of the whole; so that when we come to consider our own position relative to that of other manufacturing countries, we shall obviously be placed at a disadvantage as soon as we become dependent upon coal which is difficult and expensive to get, even though we can get it at a price.

Another consideration of importance is the tendency to replace hand labour by mechanical appliances which depend ultimately on coal for their operation. The position is, therefore, that, if we develop in the direction of employing more mechanical power, we shall consume more and more coal unless means can be found for utilizing it more efficiently; and it is with the efficiency of utilization that I propose to deal next. Before proceeding further, however, I may say that complete utilization of coal will involve its use not only as a source of heat and power, but also as a source of valuable chemical products.

The original vegetation from which coal has been derived consisted not only of the plant skeleton—substances like cellulose—but of plant juices and spores of a different chemical nature containing resinous constituents. The process of transformation into coal brought about a number of changes, but coal still retains its duplex composition, in the sense that it consists partly of cellulosic and partly of resinous constituents The differences between one class of coal and another are due largely to the proportions and the modified composition of these two constituents or groups of constituents. It is the

resinous constituents which make the ordinary house coal soften somewhat on being heated in the fire and give off large quantities of rich gassy volatile matter, containing those heavy gaseous compounds of carbon and hydrogen which make the flame luminous and smoky. It is the absence of these resinous constituents which makes anthracite coal burn with so little luminous flame and smoke. When a coal is burned on an ordinary fire, it goes through two stages. In the first place, as a result of heating alone, it gives off a quantity of volatile matter; and if this volatile matter is collected and cooled separately, it is found to consist of three main portions. There is the gas which we know as coal gas, a sticky somewhat oily liquid which we know as coal tar, and a third portion of a watery character, known as gas liquor, which is found to contain ammonia derived from the nitrogen present in the coal. The volatile matter having been expelled from the coal by heat, the residue is a porous mass known as coke. It consists of the ash of the coal, and a large proportion of the carbon—a portion which is known as the fixed carbon, because it was not driven off by heat.

The second stage in the burning of the coal is its combination with the oxygen of the air; and both the volatile matter and the fixed carbon can go through this process. In the combustion of coal as we know it in the ordinary house fire and in the steam boiler, the breakdown into volatile matter and fixed carbon, and the combustion of both, are allowed to take place on one grate and almost simultaneously. It has the advantage of simplicity, but the direct burning of coal on the domestic grate is very unsatisfactory. For one thing it is practically impossible to do it without smoke when the fire is mended. Volatile matter comes away from the coal in a thick black stream. It is not only smoke, but a tarry, sticky kind of smoke—much worse in this respect than the smoke from the larger factory furnaces. Then again, the coal fire is inefficient. Only about 20 to 25 p.ct. of the heat generated is radiated into the room, and nearly all the rest goes up the chimney. Added to these things is the labour of making and kindling coal fires and the removal of ashes. This use of raw coal in the home must be substituted by some more efficient and cleanly method of heating.

The Effective and Logical Result.

Electricity has its obvious attractions, but as far as I can see is hopeless for general domestic use on the score of expense, in terms of either money or heat units. It has to be remembered that, however efficient the electrical current may be when it comes to be applied in the home, it only carries on the average about 10 p.ct., and as a maximum about 20 p.ct., of the heat of the coal which was burned at the power station to make it. This 80 or 90 p.ct. initial loss is too severe a handicap. It entails an enormous waste which is not appreciated by the consumer because it occurs at the power station.

An effective and logical remedy lies in carbonizing the coal or gasifying it before use, separating the volatile matter from the fixed carbon as is done at the gas-works. In this way the coal can be resolved into a solid fuel, coke; a liquid fuel, tar (including motor spirit); and a clean gas—all of which can be burned without the emission of smoke, and for most purposes much more efficiently than the raw coal.

In this way the coal is resolved into a clean gaseous fuel, a smokeless solid fuel, and a liquid product, tar, of special value in itself as providing fuel oil, motor spirit, and valuable chemical products; while ammonia is recovered at the same time. The process is known as carbonization.

We will now consider how far the process is not only desirable, but thermally efficient, which means, how many heat units present in the coal are available in the products, and how far is the value of the heat unit enhanced (or the reverse) by the transformations of the carbonization process. I shall deal with results obtained in current practice.

I have already pointed out that when coal has been used for the generation of electricity the current carries from 10 to 20 p.ct. of the heat which was present in the coal burned at the power station. What is the corresponding position for gas and the other products of carbonization, as carried out at the gas-works? This can be answered by the following table, in which the fate of the heat units present in the coal is disclosed.

TABLE III.—*Carbonizing Gas Coal in Horizontal Retorts.*

Heat of combustion of coal, 100·0.	
Heat content—	
Gas	22·5
Coke sold	48·3
Tar	6·0
	76·8
Heat used and lost in manufacture	23·2
	100·0

The table represents a year's working on a gas-works plant which can be taken as typical, but not one of the most modern. It will there be seen that for every 100 heat units present in the coal which goes into the gas retorts, 22·5 are obtained in the gas, 48·3 in the coke, and 6·0 in the tar. The heat units in the total coke made is a higher figure than that shown, but some of the coke has been used for heating retorts. Altogether, the heat used and lost in the manufacture amounts to 23·2 p.ct., leaving as a total 76·8 p.ct. available in the products of carbonization—or, as this fact is usually expressed, 76·8 p.ct. is the thermal efficiency of the process of carbonization. With more modern plant, 80 p.ct. would be nearer the mark attained.

Carbonization Products.

Next comes the interesting point as to what advantages have been secured in converting coal into these gaseous, liquid, and solid products; and I propose to take them in turn. I will begin with the liquid products, because they illustrate to what an extent coal is to be regarded as a valuable storehouse of chemicals, as well as a source of energy. The watery material which accompanies the tar contains ammonia derived from the nitrogen from the coal, and it is readily convertible into ammonium sulphate—one of the most valuable of artificial manures. The tar is in itself the raw material of a great industry. By proper treatment and refining it provides us with such substances as toluene and benzene, which we had good reason a few years ago to recognize as indispensable to our national existence, providing us as they did with so large a proportion of our high explosives. The coal-tar colouring matters and many drugs represent another phase of usefulness, and two comparatively new uses have attained positions of the first importance during the past few years and are making more insistent demands every day. I refer to coal tar as a source of motor spirit, for which its lighter fraction known as benzole is admirably adapted, and to the large and increasing use of coal tar as a road binder. Apart from these uses a large proportion of the tar can be utilized as a fuel oil for the propulsion of ships instead of using coal. The use of this liquid fuel oil has a great commercial value, but it has beyond that a more special value in national defence, since it is held to be an absolute necessity for the propulsion of modern warships, and it is the only home-produced liquid fuel which we can call upon for that purpose. Another form, not so light and refined as motor spirit nor so crude as fuel oil, is used in the so-called Diesel engines on the internal combustion principle. We see then the high degree of value which can be created by proper use when the more resinous constituents of coal are led to form tar, as they do in carbonization practice, instead of forming smoke, which they are too apt to do when coal is used directly in the open grate.

Let us now consider the gas. Here I must speak again of thermal efficiency, because it is so important in this connection. I will do so with special reference to the open fire, which is the most favoured method of heating rooms in our houses and is, in my opinion, likely to remain so, whatever fuel may emerge in time as being the most satisfactory for burning in it. The peculiar value of radiant heat as thrown out from a fire has been appreciated by generations of our countrymen and countrywomen; and recent physiological work has shown that this peculiar excellence was by no means imaginary, but had a sound scientific foundation. But when we use raw coal in an open fire, we pay a big price—too big a price in many ways—for its cheery blaze. It is both dirty and inefficient; and the dirt it creates in the home, and the work it entails there are not the end of the story, which is continued by the smoke leaving the chimney. The inefficiency of the coal fire is best seen when one compares it with the gas fire. For every 100 heat units supplied to a modern gas fire, practically half is radiated into the room, while with a coal fire the radiated heat is less than a quarter of that supplied in the coal. In both these cases there is, of course, a proportion of heat which goes up the chimney. In the case of the coal fire it is inordinately large, but in the case of the gas fire it is reasonable in amount, about one-quarter of the total. I say it is reasonable in amount because a certain quantity of heat going into the chimney does perform the useful function of ventilating a room; and as the ventilating function of the open fire is probably as important as its heating function, a certain amount of heat may very well be devoted to this purpose. The trouble with the coal fire is that the proportion used in this way is ridiculously large, wasting fuel, and over-ventilating the room to the extent of creating draughts. The gas fire is economical in the way in which it utilizes the heat units brought by the gas for the combined purpose of heating and ventilating, which it does in an economical and practically convenient manner. It is sometimes said in extenuation of the very low thermal efficiency of electrical generation that the efficiency of an electrical heating appliance can be taken as 100 p.ct. But plainly this can only be the case if no air goes into the chimney hot enough to produce the ventilation which is so essential, and in that case an auxiliary ventilating appliance must or should be provided.

This high efficiency of gas for room heating is typical of what it can do in many other uses, because it is so subject to simple and exact control that apparatus can be designed for burning gas of a much more refined and scientific construction than can be contemplated for the burning of coal. Moreover, not only is gas clean in the ordinary sense, but it has been purified from nearly all its sulphur compounds at the gas-

works, while it has to be remembered that every ton of raw coal which is burned in even the most modern steam-raising plant of a factory or electrical generating station turns out about half-a-hundredweight of sulphurous acids into the atmosphere. In this respect gas is superior not only to raw coal, but to the smokeless solid fuels.

Nor is it to be forgotten in these days, when the electric motor has rightly come to occupy such a strong position for the provision of power, that the gas engine is thermally more efficient than any other type of prime mover known to practice, and that Sir Dugald Clerk has expressed the opinion only recently that, where a small isolated unit of power is required, a gas engine using town gas is still the most economical plant available from both the thermal and the monetary standpoints.

COKE, AND THE TEMPERATURE OF CARBONIZATION.

I will now pass on to consider the solid smokeless fuel, or coke, resulting from carbonization. This is a subject to which the public attention has been very much directed lately by numerous utterances—æsthetic, hygienic, scientific, technical, and political—displaying very varying degrees of competence and impartiality. It may, however, be taken as agreed that for those domestic purposes where solid fuel continues for any reason to be used, it should be of the smokeless kind. There is no chance of our attaining the ideal of the smokeless city until that principle is applied.

The coke produced by the ordinary gas-works process is a form of solid smokeless fuel which is at the present time produced in large quantities. Other methods have been suggested and are being tried which have been grouped under the heading of low-temperature carbonization.

Now it is to be remembered that in the earlier days of the gas industry gas was made in iron retorts, which meant that of necessity lower temperatures were employed than are in common use to-day. The plain fact is that the development of the gas industry has proceeded in the direction of making more gas from the coal; and there is a sound reason for this, because every heat unit secured after the transformation of the carbonization process in the form of gas is, from every standpoint, thermal or monetary, worth so very much more than a heat unit in coal, and this appreciation in value is so much greater in the gas than it is in the tar or the coke.

The changes in gas practice have been in the direction of using higher temperatures, or even of gasifying some of the coke either in the gas retorts or in separate generators. The reversion to low-temperature carbonization is not easy to justify. The carbonization process has to be considered as a whole, as one yielding four main products—gas, tar, ammonia, and coke. Merely lowering the temperature gives very much less gas—say, about half. More tar is produced, not of a kind containing benzene or toluene, and more difficult to refine, but probably yielding more motor spirit. The ammonia is less. The coke is softer, easier of ignition than ordinary gas coke, and burns with more flame, but is more liable to crumble in manufacture and transport.

To counterbalance the loss of the high gas yield does appear to be an exceedingly difficult problem, as is now coming to be realized. I am far from saying that it is insoluble, but it would appear to necessitate either obtaining a very high order of value in the bye-products, or evolving some process of carbonization very much less costly than has hitherto been used; and neither of these is the easy thing to do which optimistic utterances would suggest.

The production of smokeless solid fuel, however, is not necessarily bound up with low-temperature carbonization. Low temperature is only one of the factors involved. The transmission of heat through coal during coking, the physical and chemical changes which occur, and the extent to which the carbonization process can be speeded up and modified by proper preparation of the coal, all require exploration. The gas industry is becoming increasingly alive to the possibilities in this direction, to the necessity for thorough and systematic examination of all the factors operating in the carbonization process, and an investigation of what can be done, for example, by proper preparation of the coal, which may involve washing, grinding, blending, and briquetting, or even the addition of some inorganic constituent—for, strange though it may seem, the presence of some of the ash constituents, such as oxide of iron, has been shown to exercise a marked influence on the coking process and the nature of the coke produced. The further control of the quality of coke and its supply in a form which is not crumbly, but easily ignited, burning cheerfully and not leaving too much ash, is one of the most interesting things with which the gas industry is now occupied.

I may, however, at this point indicate that undoubtedly the best utilization of smokeless solid fuel will also be greatly helped by a more careful study of the best construction of grate for burning it, since the grate as at present used has been evolved for the burning of raw coal, the requirements of which are somewhat different. There is little doubt that, if the house grate of to-day was slightly, but suitably, modified in construction, quite a hard coke would burn well in it. As regards the efficiency obtainable from coke, all the tests made by Dr. Margaret Fishenden, on behalf of the Fuel Research Board, indicate that it is appreciably higher than that obtainable from raw coal (which is all to the good), though nothing like so high as that obtainable from a gas fire.

Enough has now been said to indicate clearly that, apart from other considerations such as those of cleanliness and hygiene, the gas industry is entitled to put forward the claim that, on the basis of thermal efficiency alone, its methods of dealing with our coal supplies represent the highest order of actual achievement in the present. What it may be able to do in the future it is not possible for any one of us to foretell. Its problems become more interesting every day, necessarily more complicated, and make more demands upon those engaged in it. But the position of the gas industry is scientifically sound; and by systematic and patient research and trained intelligence applying the results of research to technical and commercial developments, that position can be made even more assured.

CONSERVATION OF THE NATION'S VEGETATION.

THE EFFECT OF SMOKE ON PLANT LIFE.

By ROBERT W. ASCROFT, M.B.E., F.R.H.S., late of the Food Production Department of the Board of Agriculture.

[Extracted.]

Smoke alone is responsible for an immense amount of damage to living vegetation; but when combined with mist in the form of a dense smoke fog, it may play havoc with plant life. Our country will always be subject to water fogs; but it is quite possible that without smoke London and other towns would be far clearer and sunnier at such periods than the country. Dr. J. S. Owens, lecturing this year before the Royal Society of Arts, suggested that the water fog is partially evaporated by the higher temperature above a city, but that its place is taken by smoke which, in the absence of wind, is dammed up and collects in a heavy pall. Those who are interested in horticulture and agriculture realize the damage which is caused each year to the trees and plants throughout the country by lack of light, deposit of tarry matter on the leaves, and the pollution of the atmosphere with sulphur dioxide, yet they take no active steps in the matter.

The burning of coal as usually conducted pollutes the atmosphere in two ways—first, with the visible solid impurities or soot; and, secondly, with the invisible sulphur dioxide which results from the combustion of sulphur compounds present in the coal. The sulphur dioxide slowly oxidizes to sulphuric acid in the presence of moisture. Dew or rain will carry down in solution both sulphuric acid and sulphurous acid (= dissolved sulphur dioxide), and deposit them on vegetation and soil.

The character of the soot itself varies considerably, according to the different conditions under which coal is burned in the home and factory. Some extremely interesting and valuable experiments have been carried out in the Agricultural Department of the University of Leeds, and at the experimental farm connected therewith at Garforth, which lies about 7 miles east of the city in an industrial district. Analyses show that boiler (industrial) soot contains a greater quantity of ash grit but very little nitrogen, and this is therefore not of much use as a fertilizer for the crops. Domestic soot is far richer in nitrogen, but contains a very large proportion of tar.

It must be remembered that in the distillation of coal for the making of gas, almost complete elimination of sulphur occurs—it is actually recovered as such, at the gas-works. As a consequence of this, the coke (or smokeless solid fuel) and gas together contain far less sulphur than the coal from which they were produced. They therefore yield much less sulphur dioxide when burned. Moreover, sulphurous acid or sulphuric acid are much more harmful to vegetation in conjunction with smoke than alone, as the sooty deposit helps to retain the acid in contact with the surface of the leaves. There is no intention in this paper to advocate the use of any special means of heating; but the extended use of gas, coke, and electricity would certainly help to diminish the amount of sulphurous acid, and therefore reduce the damage caused to living vegetation. In some districts the presence of smoke and fog causes an earlier leaf-fall in the autumn, and as the trees have a shorter season of growth the annual rings become narrower. This can be seen quite clearly if specimens of affected trees are examined. Such plants as hollyhocks and primroses will often not survive more than one winter; but those with a hard, smooth, leathery type of leaf with thick epidermis, like many carnations, auriculas, and irises, succeed fairly well. In a smoke-infested area the grass is coarse and poor in quality, and farmers find it difficult to provide adequate grazing for their cattle. This is a matter of considerable economic importance to the agriculturist. The acid present in the smoke lowers the nutritive value of the grass, with the result that the farmer is obliged to incur additional expense in the purchase of foodstuffs for feeding his stock. The soil in these areas will also suffer loss of lime for the same reason; and, as the grass itself will be poor in this substance, the lime content of milk obtained from cows feeding on pasture close to large towns will tend to be lowered. Lime is essential to the well being of young stock; and its

absence from pastures near towns accounts very largely for the difficulties which farmers experience in breeding sheep.

Dr. Crowther, when lecturing in 1912 before the Royal Horticultural Society, described in detail experiments carried out with grass grown in boxes under glass for protection from the rain, and then watered at intervals with water free from, and containing varying proportions of, sulphuric acid. It was found that the numbers of useful bacteria decreased rapidly as the acidity increased, with the result that ammonia production, nitrogen fixation, and the actual production of nitrates in the soil were all diminished. Prof. Cohen, of Leeds, found that 1 gramme of soil watered with neutral rain water at Garforth contained as many as 5,228,000 bacteria, while in the soil watered with acid rain water the number was reduced to 1,690,000.

In the autumn of 1891, after a period of fog, Prof. F. W. Oliver, D.Sc., carried out many experiments with the deposit removed from the roofs of the greenhouses belonging to Messrs. Veitch, of Chelsea. He first of all dissolved this deposit in a little distilled water, and then, after selecting various plants, including hydrangea hortensis and bouvardia, he painted one-half of each leaf with the solution, and the leaves were kept moistened with water from day to day. The highly cuticularized leaf surface of the hydrangea protected the plant from damage, but within a week the bouvardia showed signs of injury. From the substances collected in the deposits, Prof. Oliver then selected powdered metallic iron, red oxide, magnetic oxide of iron, and sulphuric acid, as possible causes of the damage; and with these he experimented separately. A little distilled water was added to the oxides, and a thin layer of paste was then spread on the leaves. The oxides had practically no effect; but the metallic iron destroyed the epidermal cells although it did not do any further damage, as the iron was then entirely oxidized. With the sulphuric acid, however, the damage was very marked; and even with a 0·05 p.ct. solution, damage was apparent after a few days. With a 0·5 p.ct. solution, the damage was noticeable within 12 hours, and many leaves fell shortly after.

The following figures, published in 1891 by University College, Gower Street, London, show in a very striking manner the increase in the amount of sulphurous acid present in the atmosphere during a fog. Known volumes of air were passed through a continuous drip of hydrogen peroxide which absorbed the sulphurous acid.

		Milligrammes of Acids per 100 C.Ft. of Air.
Nov. 5	Dull	5·40
,, 6	,,	4·73
,, 10	,,	6·80
,, 13	,,	5·66
,, 17	Slight fog	8·16
,, 20	Dull	6·80
,, 24	Slight fog	10·24
,, 30	Dark and very foggy	17·10
Dec. 21	Yellow fog	20·52
,, 22	Dense black fog	39·06
,, 23	Yellow fog	12·96
,, 24	Thick yellow fog	20·40

One winter during the war, the lake in the Royal Botanic Gardens, Regent's Park, where the ice was thick, was made impossible for skating, because, as the result of a heavy fog, it had become covered with grease, so that skates slipped and would not bite. It was not until heavy snow had fallen that the grease could be scraped off. Mr. J. L. North, the Curator of the Gardens, put forward the interesting suggestion that this deposit was partly due to the oily exhaust from motor cars; but figures sent me by Dr. J. S. Owens show, I think, that the tar produced from the use of inferior coal was the probable cause. In the tarry matter of the residues deposited on glasshouses are such substances as pyridine and phenol, which appear to be of an exceedingly poisonous nature as far as plants are concerned; and the former substance is possibly responsible for the yellow discoloration which takes place in many flowers which have been exposed to fog.

Not only does the toxic effect of fog often result in severe damage to plants or even in their death, but it diminishes light and checks transpiration. Under glass during a fog, watering should be reduced to a minimum and the temperature kept as low as is consistent with the safety of the collection. The more greedy a plant is of sunlight, the more it will suffer, as not only is transpiration checked, but the effect of the reduced light is to check the assimilation of carbohydrates so that very little starch is formed. Coal smoke often affects the colour of flowers, and as a rule the greater the pollution the paler the tint. Visible smoke reduces the amount of light that reaches the leaves, besides blocking-up the stomata or breathing pores through which carbonaceous food is assimilated. Lastly, smoke affects the vitality of the plants.

The evils of smoke pollution are made very clear by these various facts. What remedies can be suggested, and how can they be effected? Interest must be aroused in the subject, so that the public can realize the urgent necessity for immediate action. There is no need to do away with all open fire places, if smokeless solid fuel can be provided at the same cost as raw coal, though convenience and saving of labour are factors strongly favouring the displacement of crude coal by gas. But all the old kitchen ranges should be replaced by gas cookers, and water should be heated by coke boilers or gas water heaters. Electricity will provide power for running the railways; and gas, electricity, and oil, power for industrial purposes. Gas mainly, but electricity in certain special cases, will meet the industrial needs where heat is required. For domestic heating, gas will be the fuel of the future on account of its comparatively low cost and its great convenience and cheerfulness.

All this means progress and a cleaner, healthier country. It is time that horticulturists and agriculturists took a more active interest in a matter of such vital importance, and helped to bring about this peaceful revolution. The subject of smoke abatement is not one which concerns the townsman only, but is the affair of every dweller in these islands, whether his or her chief business lies in a rural or an urban area.

CONSERVATION OF HUMAN ENERGY.

By Dr. R. VEITCH CLARK, M.A., M.B., Medical Officer of Health to the City of Manchester.

[Extracted.]

In estimating the position held by a country or a people in the world's affairs, the resources of that country have always been taken as the standard upon which the judgment of position is made. There is no doubt that material resources constitute a basis of wealth and power which, other things being equal, is bound to result in greater prosperity for the country happy enough to possess them. But in real fact the only genuine asset possessed by any race or country is the mental and physical efficiency of its people. Anything, therefore, which will improve the well-being of a race is deserving of our profoundest attention and our ablest and most concentrated thought.

There can be no doubt but that the aggregation of the population into densely packed communities has seriously affected our individual welfare. One of the most profoundly depressing things which exists in this country undoubtedly is the gloom which surrounds us, particularly during the winter months, in the great industrial belts of England and Scotland. This gloom is due to one thing and one thing only—the pollution of the atmosphere with smoke and the other products of combustion of raw coal. The abolition of smoke from our midst—a thoroughly feasible proposition—would do more for the improvement of public and individual health in our industrial centres than any other single action open to this country.

Everyone feels the stimulating effect of a fresh and sunny summer morning, and it is few indeed who do not react in the other way to the depression of atmospheric dinginess. This psychology of light is an enormously potent factor, and its actual material results have been demonstrated by the Industrial Fatigue Research Board in that the output of work was found to be notably diminished when lighting conditions were bad.

In the vegetable world, generally speaking, the whole of plant life depends upon the action of the sun upon the green colouring matter, chlorophyll. Plants grown in the dark or without sunlight are pale and sickly and weak in development. In normal circumstances the effect of the sun is to develop fully this pigment, and through subsequent chemical interaction in the plant there are built-up the carbohydrates and proteins which give to plants their food values. The vitamins, which are of such essential value in fresh food as preventives of scurvy, rickets, incomplete development of the bodily framework, and many other conditions, are all the direct or indirect result of the stimulating action of the sun upon vegetation. All the food values of vegetables, root crops, fruits, or ordinary green vegetable food are therefore directly dependent upon the sun's rays. In man we have abundant proof equally from many extensive scientific investigations of his need of sunlight. Dr. Chick, of Vienna, has demonstrated that the absence of sunlight is one of the most potent factors in ordinary circumstances (apart from starvation) in the production of rickets. Either absence of vitamins or the absence of sunlight therefore produces rickets. Diet unusually rich in vitamins can, to a certain extent, replace the sun, but with a relatively poor diet and abundant sunlight rickets does not develop. Our knowledge of the physical condition of children in industrial centres and the prevalence of rickets among them is very largely explained by these researches. It would be difficult to exaggerate the importance of the facts which are thus revealed.

A striking piece of work carried out at Columbia University in the United States of America revealed the remarkable fact that the chemical constitution of the blood in the human being varies according to the seasons, inasmuch as the phosphorus and calcium (or lime) in the blood are at their lowest in March and highest at the end of summer and autumn. This shows how the sunny part of the year acts as a stimulant to the whole bodily metabolism.

Children and adults suffering from such advanced tubercular disease of the joints, skin, &c., as by other modes of treatment would be utterly hopeless have been completely and to all evi-

dence permanently cured by exposure to the sun's rays. This applies to all types of non-pulmonary tubercle; and not only is the cure permanent, but the mobility of the tissues, freedom of movement of the joints, smoothness and suppleness of scars without a single surgical intervention, constitute one of the most remarkable triumphs of modern medical science. Equally true is it that sunlight cures rickets. The sunlight cure is rapidly extending its boundaries, and many septic conditions and other conditions of ill-health appear to be permanently benefited by a course of this treatment.

One might amplify in other directions the profound influence which sunlight has upon the bodily welfare of the individual, but enough has been said to demonstrate the properties possessed by solar radiations, and the importance of adopting any procedure which will enable those radiations to reach our bodies in the natural way in ordinary life. The passage of ultra-violet rays is greatly interfered with by even a slight smoke haze. Not even so much as the greyish sky which is supposed to be the natural condition in our industrial areas, but a much less pronounced haze through which the ordinary sunlight can to a considerable extent penetrate, is enough to filter-off a large proportion of the ultra-violet radiations. How much more then does the ordinary smoke cloud deprive us of this source of health and well-being. In addition to the deprivation of sunlight the presence of smoke in the atmosphere has a profound effect inasmuch as it actually fouls the air we breathe. Soot becomes deposited in the lungs and glands adjacent. The whole of the lining of the breathing passages is polluted and markedly irritated by the soot, acids, and tarry matters contained in the air. This has a most serious effect upon the whole respiratory mechanism; and the death rate from respiratory diseases immediately leaps up with the incidence of fog and lack of sunlight. All chronic conditions of the nose and throat, bronchitis, broncho-pneumonia, and similar diseases are unquestionably aggravated by smoke and smoke fogs. If our water were as dirty as our air we would either have a revolution or we would cease to exist.

I do not claim that the abolition of the smoke evil will abolish even one disease, but it will greatly diminish the incidence of disease. It will incomparably enhance the mental and physical happiness of people. It will favour very largely the development of a happy childhood and adolescence, and *pari passu*, the production of a greatly enhanced efficiency in adult life.

It is recorded by Sir George Newman in his last annual report to the Ministry of Health that one of the most distinguished foreign Medical Officers of Health recently visiting this country, when asked what impressed him most in England, replied that it was the neglect of vaccination in the country of Jenner, the bad crowded housing conditions, and the smoke pollution of the atmosphere. It is our duty as a nation to get rid of this reproach. It is a crying evil due to a neglect both unbusiness-like and inhuman.

Discussion.

Dr. A. T. NANKIVELL (Medical Officer of Health of Plymouth) said he had very much pleasure in moving a hearty vote of thanks to Dr. Veitch Clark; but he had nothing to add to what was included in his admirable paper. They all knew, and had known for many years, the great value of sunshine; and that sunshine could be had in England they were equally well aware. He did not know whether he ought to suggest that it might be possible for local authorities in the future to give grants to domestic houses, and possibly even factories, which did not produce smoke. It did not seem very difficult. If a local authority were building houses, surely it was not much more difficult to put in gas heating than dirty coal. Generally speaking, grants-in-aid were a very excellent way of getting anything done; and the local authority might say: "Here is a house not producing smoke of any description. We will reduce your rates." ["Hear, hear."] Whether they could do this, he did not know. They might, where they owned the gas supply. But it did seem to him to be a practical way of securing smoke abatement. People were anxious to get something off their rates; and they did not object to the modern gas fire, which was a most admirable way of warming a house, and which ventilated a room quite as well as an ordinary coal fire.

Mr. F. W. GOODENOUGH seconded the vote of thanks, and included the readers of the other two papers, which the mover was not present to hear. He did this, because the subject came together as a whole; and it was as a constructive piece of propaganda for smoke abatement that the morning's programme was so satisfactory. He thought the gas industry could be very proud of those who had come to speak on that platform. ["Hear, hear."] They were proud of their cause, because they knew it was founded on truth, and that the ideals for which they were working were ideals for the benefit of the nation as a whole. It was a very great satisfaction to all connected with the organization of the Association that they should have had three such advocates of smoke abatement as Prof. Cobb, Mr. Ascroft, and Dr. Veitch Clark. By his dispassionate, but deadly, analysis of the fuel problem, Prof. Cobb had done a really good service to the nation. He (Mr. Goodenough) was not speaking only of the gas industry itself, which was a small matter. They did not want to exist if they could not serve the nation. Prof. Cobb had done a great service to the nation by his destructive and constructive analysis of the fuel problem. This was followed by Mr. Ascroft, and concluded by Dr. Veitch Clark's earnest plea for more light, leading to health of mind and body for the nation as a whole. Then they got an endorsement of that from Dr. Nankivell, with the first suggestion for a sensible subsidy that they had heard recently. [Laughter.] So they could well include him in the vote of thanks, because he had come to support his brother Medical Officer. [Applause.]

Prof. COBB, returning thanks, said it had been a great pleasure to him to hear his two colleagues, if they would allow him to call them so, put forward the subject so admirably from another point of view. He questioned whether it could have been done better. What they had to say was of surprising interest. It was extremely encouraging to the gas industry, and to those of them who were trying to do their best in their own way to get this matter put right, to have this definite, this clear testimony of well-informed, competent medical observers, who were themselves interested in the subject, that what they were doing was not only likely to be of economic advantage, but likely to be, what was even more important, of the greatest human service. Dr. Veitch Clark and he were old friends; and he was pleased to see the extent to which he had retained his humorous and earnest method of presenting a paper. Mr. Ascroft was speaking on another branch of the subject; and if he might be allowed to refer to Leeds, he might say he was pleased to gather once more the extent to which work that had been so largely initiated by Prof. Cohen, and continued by Dr. Ruston, with special reference to vegetation, held a place in his mind in this connection. But the main thing was that the authors had attempted, to the best of their ability, to show from very different points of view that this subject was of dominating importance, and that the gas industry was making every day a very valuable contribution to the solution of this most important problem.

Mr. ASCROFT remarked that the opportunity of coming to the meeting had been particularly welcome to him, because it had given him a chance of making many new friends in a branch of industry with which he had never come in direct contact before. He very much appreciated the kindness they had extended to him in letting him urge the importance of smoke abatement. In the work he had to do during the war in connection with food production and investigation of damage to crops, he was constantly seeing, especially in the Midlands and the North, the enormous losses which the country was suffering.

Dr. VEITCH CLARK said one little fact he wanted to mention—and he was glad to have the opportunity of doing so now—was that in their new housing schemes to a very considerable extent (anyhow, certainly in Manchester) the houses were being provided with only one ordinary coal fire. All the other fires were gas fires, and this applied to houses of four, five, or six rooms. Thus there was a definite step being taken towards the elimination of domestic smoke, which was unquestionably at least 50 p.ct. of the smoke that caused the damage. One suggestion he would like to put forward—it was not in the nature of a subsidy, but he thought was quite feasible—was that there ought to be legislative power given to local authorities, in connection with the provision of appliances for new works, that these appliances should not be approved unless a guarantee was given that the equipment would be non-smoke producing. This would not be placing any serious difficulty in the way of industry; it would not be asking people to convert plant. But it was sheer lunacy to go on approving of things they knew to be wrong.

The PRESIDENT said there was still plenty of time for discussion. Might he express the hope that some lady would start it? He did this because they had had a lady of particularly sunny disposition to talk to them the night before, and while she was speaking, he thought, "What is the real groundwork of this amazing vitality?" It was that she had been a "child of the sun" from birth. Born in Virginia, she had homes now in the full eye of the sun.

Mrs. M. A. CLOUDESLEY BRERETON remarked that, as there had been a challenge thrown out to women, she would say a few words, although that morning was not quite so appropriate an occasion, perhaps, because the question of the conservation of energy had been dealt with on a plane that was not so domestic as on the previous day. The great problem before the women who had to bear children and bring them up was one of energy in the broad sense. However poor a woman was, there was no home which one woman, while she was bearing a large family, could entirely run. She thought the type of woman who would help them to run homes in the future would be the trained lady, who did twice as much work as an uneducated woman. It was possible for educated women to run homes—their own and other people's homes, if they were properly designed—and even the poorest woman, if she could have all these appliances and a little home help in times of illness, would be able to get along. This was how the servant problem would be solved. In the gas industry they were solving the servant problem by solving the service problem; and this was conservation of every kind of energy, human and otherwise.

Mr. H. D. MADDEN (Cardiff) said there was one point in Prof. Cobb's paper that he should like to stress, because he thought it was important. This was in relation to the heating of the rooms in which the people lived. During most of the winter months, they spend a great deal of time in their homes. They had heard a lot about the radiant heat of the sun; and it did seem to him that, through the "B.C.G.A.," they should bring as strongly as possible to the notice of the nation the fact that the gas fire gave out a large proportion of radiant heat in the living room, at the same time that it ventilated it. He had been much struck with the ignorance of some general medical practitioners with whom he had been brought in contact. They did not seem to understand, even in the crudest way, the injector action of burners and the ventilating effect of gas-fires, and the amount of radiant heat that the gas-fire would give out. Neither did they realize the effect of convected heat in a living room. He had pointed out to them that convected heat did not ventilate—he did not care whether it was electric or otherwise—and that the human effluent of the lungs was breathed again and again in that room. If they could stress the radiant value of gas fires, and their ventilating effect, they would do a great deal to cure the smoke problem in this country.

The PRESIDENT remarked that now he would like to say a word

on these admirable papers. It struck him when Prof. Cobb was talking of what food for thought he had given them in one of his tables. In Table II., they would see that lignites had from 60 to 70 p.ct. of carbon, and bituminous coals from 75 to 90 p.ct. Between the highest figure in one case and the lowest in the other there was therefore a difference of only 5 p.ct. As a commercial man, it appeared to him that there was here much food for reflection—living, as he did, in Devon, near where these beds of lignite were—and food for reflection not only for them, but for the colliery proprietors in the North. With only this small difference between the two, if the coalowners resumed delivery of that combination of stones and soot that they gave them during the war, they had far better use their local material. It was a thing they had to think about. Everybody must have regard for the flexibility of the gas industry. If they could not have the resources of Nature which made for heat in one way, they might have them in another. Mr. Ascroft's paper appealed to him beyond measure. He had followed the legal profession, and he had also followed a far older profession than that. He was a gardener; and he knew the value of the gas industry. He had bought from one of the eminent nurserymen he referred to plants which it had been said were greenhouse plants, and must be grown in greenhouses in this country. Ten miles from Plymouth they flourished like weeds. At Kew and elsewhere they could not grow them. Look at what they missed! Again, he had seen at Chelsea recently specimens of plants which he would be ashamed to see in his garden. And the gas industry helped the gardener in more ways than that. He lived in a backwood in a little cottage. The trees were old, and he did a great deal of tree surgery. He let in the sunlight if he found a tree going wrong. He cut off the offending and decaying branch; and in accordance with the best practice recommended by Kew, he used creosote. The trees healed, and one knew no more than with Dr. Saleeby's children that they had ever been disfigured. With reference to Mr. Ascroft's paper, he should mention that letters had been received from Sir Daniel Hall, Chief Scientific Adviser to the Ministry of Agriculture; Lord Lee of Fareham, who was Director-General of the Food Production Department during the war; Dr. Arthur W. Hill, F.R.S., Director of Kew; and Dr. A. B. Rendle, F.R.S., President of the Linnean Society. The third paper appealed to them more than anything. It dealt with the question of their own health and strength; and he promised Dr. Clark and their own Medical Officer of Health in Plymouth that they would co-operate to the extent of their power in every direction to give as much sunlight as possible. And what they were doing in Plymouth was but small compared with what the industry he had the honour to represent there did throughout the length and breadth of this land.

GAS CENTENARY AT SOUTH SHIELDS.

PROGRESS AND DEVELOPMENT, 1824-1924.

[From a Commemorative Booklet Prepared by the South Shields Gas Company.]

According to historical records, it is stated that on Dec. 5, 1823, circulars were sent to about 350 inhabitants of South Shields by certain local tradesmen, inviting the recipients, if interested, to attend a meeting at "Oystons," for the purpose of considering the question of establishing a company to supply the town with coal gas light. The meeting was duly held on Dec. 9, 1823, presided over by Mr. William Chapman. It was stated that a capital of £4000 would be necessary to carry out the proposal, and that a revenue of about £600 might be obtained. It was forthwith agreed to establish a Company, which was to be called the South Shields Gas Company, with a capital of £4000, divided into shares of £25 each; any member being at liberty to acquire an unlimited number of the shares. The Company was formed by Deed of Covenant dated March 17, 1824, for the purpose of supplying the townships of South Shields and Westoe, in the County of Durham, with coal gas for the lighting of houses, buildings, and streets in the said townships. According to the census of 1821, the population was stated to be 16,503.

The first works of the Company were constructed near what was then called "Paradise," on the south side of the Mill Dam, and the first Engineer Mr. Sanderson. Gas was first supplied to the houses and shops in the town on Oct. 1, 1824.

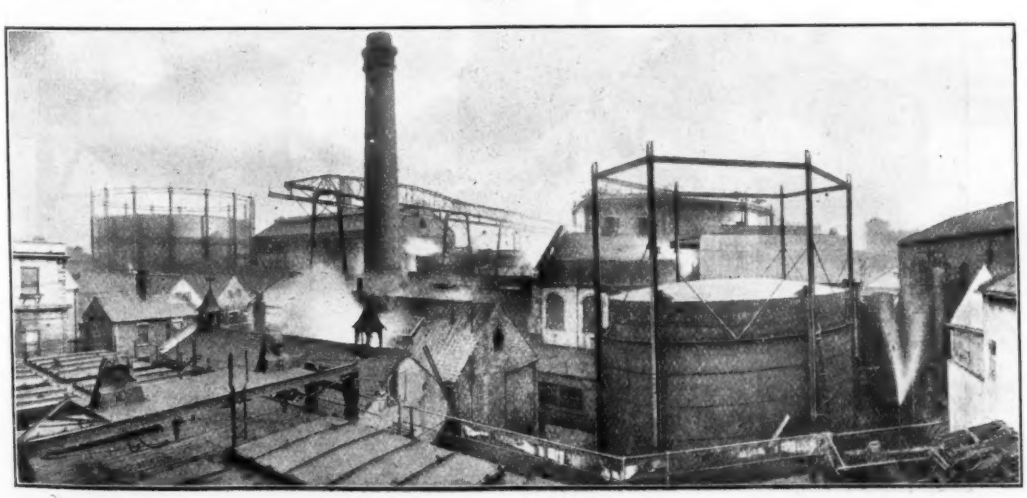
On Nov. 1, 1829—five years after the Company's inauguration—the Town Commissioners lighted part of the town with gas; twenty lamps being provided and lighted for the first time. The cost of the public lighting at this period is recorded to have been at the rate of £2 5s. per lamp for the six winter months; it being then the practice not to light the lamps for seven nights at the time of the full moon. In 1845 the number of public gas lamps had increased to 178.

During the year 1853, an Act entitled "South Shields Improvement" was granted to the Corporation, in which, in addition to other powers, they were authorized to borrow the sum of £10,000 for the purpose of purchasing the gas-works in the borough; but, as the paid-up capital of the existing Gas Company was at that time considerably in excess of the amount the Corporation were empowered to expend in purchasing the undertaking, the transfer was never effected. Up to 1856—that is, a period of 32 years after the date of inauguration—the Company was carried on as an ordinary private trading concern; but the capital had then increased to £15,293. In the year mentioned, the Company was registered under the Joint Stock Companies Act, with a capital of £20,000, in shares of £10 each; and power was also obtained to increase the capital to £35,000, the number of shares issued at this period being 1969. During 1857, the Company made a great advancement in status by being incorporated by Act of Parliament with a share capital of £40,000, bearing 9 p.ct. standard dividend; and a loan capital of £9800 was also authorized. In the Act of Incorporation, the maximum price of gas was fixed at 4s. 6d. per 1000 c.ft., and the limits of supply were the Borough of South Shields and the Parish of Jarrow. At this important period in the Company's history, the Chairman of the Company was Mr. Robert Dawson, who held the position until 1858, during which year his death took place. He was succeeded in the chair by Mr. Robert Wallis.

In the following year the Company installed plant for the manufacture of sulphate of ammonia. Mr. Sanderson retired from the position of Manager in 1863, after having been in the service of the Company for 40 years; and Mr. W. J. Warner was appointed Engineer. In order to meet the increasing demand for gas at this period, it was found necessary to extend the carbonizing plant; and the foundation stone of the new retort house was laid by Mr. Wallis on June 10, 1864.

JARROW GAS UNDERTAKING PURCHASED.

In 1864, consumers of gas at Jarrow having expressed a desire to be supplied from the South Shields Company, the Jarrow Gas Company opened negotiations with the Directors of the South Shields Company, offering for sale the Jarrow



GENERAL VIEW OF THE SOUTH SHIELDS GAS-WORKS.

Gas-Works. The Jarrow gas undertaking was eventually purchased.

With increasing responsibilities, the Company had, in 1867, to again make application to Parliament for an increase in capital, when, as a result of the application, an Act was obtained authorizing £40,000 additional capital, bearing a 7 p.ct. standard dividend; and a further £10,000 of loan capital was also authorized. In this Act the maximum price of gas was fixed at 4s. per 1000 c.ft. for gas supplied within the Boroughs of South Shields and Jarrow; and the limits of supply having

Sir James Readhead, Bart., J.P., Chairman.

been extended to include the Parish of Boldon, the maximum charge for the extended area was fixed at 5s. per 1000 c.ft. At this period the sale of gas amounted to fully 73½ million c.ft. per annum, and the coal carbonized totalled 10,839 tons.

Since the inception of the Company, extensions of works, plant, and mains were frequently necessary to cope with the ever-increasing demand for gas; and during 1871 the Company commenced laying mains to East and West Boldon, and to Boldon New Winning. In 1873 it became evident that the then existing works at no distant date would be unable to cope with the increase in gas consumption. Consequently the Company purchased additional land at Jarrow, on which new works were constructed, and put into service during the winter of 1876. After half-a-century's operations, the capital had increased to £55,559, and the sale of gas amounted to 112 million c.ft. per annum; the population supplied being estimated at about 75,000.

During 1877, the Company had the distinction of being one of the first gas undertakings to hold an exhibition of gas apparatus, which turned out such a great success that the example set was quickly followed by other companies. It is interesting to note at this stage that in 1877 the Corporation of South

Mr. Dugald Currie, Engineer and General Manager.

Shields obtained powers in their "Extension Act" to purchase the gas-works and undertake the supply of gas or other artificial measures of lighting.

To meet the further development of business, the Company in 1879 again promoted a Bill in Parliament, and were successful in obtaining an Act whereby the then existing share capital of £80,000 was converted and consolidated into £91,500 of stock, with a standard dividend of 7 p.ct., and a standard price of gas fixed at 3s. 3d. per 1000 c.ft. By this Act the stock capital was further increased by £80,000, and £20,000 additional loan capital was also authorized, making the total authorized capital after the passing of the Act amount to £171,500 in

VIEW OF RETORT HOUSES AT THE JARROW GAS-WORKS.

stock and £39,800 in loan. Up to this period, the Company was a maximum price undertaking, but in the Act of 1879 the sliding-scale for the regulation of dividends was, for the first time, introduced and applied to the Company; the rate of dividend and the standard price of gas being fixed as aforesaid—the latter being applicable in respect of gas supplied in the Boroughs of South Shields and Jarrow and the district of the local Board of Health of Hebburn. The standard price for districts outside the places mentioned was fixed in the new Act at 4s. per 1000 c.ft.; and the limits of supply were extended so as to include the Parish of Whitburn. The sale of gas at this period amounted to 168 million c.ft. per annum, and the coal carbonized to about 17,000 tons. In this connection it should be mentioned that during the same year there was introduced at the Jarrow Works mechanically operated stoking machinery, invented by the Company's Engineer, Mr. Warner, which attracted a good deal of attention from engineers throughout the country.

At this period the continued progressive policy of the Directors was further demonstrated by the Company letting out gas apparatus on hire, which resulted in an enormous increase in gas consumption. As already mentioned, in 1879 the sale of gas amounted to 168 million c.ft., while six years later, in 1885, the consumption had increased to 285 millions. The number of public gas lamps had also increased to 1935, and 76 miles of mains had been laid throughout the area of supply. Owing to the continued progress and expansion in the Company's business, it was necessary at this period to acquire additional land adjoining the South Shields Works, on which to erect a new gasholder of about 1,500,000 c.ft. capacity.

The year 1886 found the Company again in Parliament; and an Act was passed granting another increase of capital by £120,000 stock and £30,000 loan; the limits within which the Company were to supply gas were also extended, so as to include, in addition to the existing limits as defined in previous Acts, the townships of Fulwell (detached), Southwick (detached), and Monkwearmouth (detached)—all forming part of the Parish of Monkwearmouth. The authorized capital now amounted to £219,500 of stock and £69,800 of loan; the number of consumers at the end of the year mentioned being 6365, and the total gas sales about 292 million c.ft.

During 1898 Mr. Wallis died. He had sat on the Board for half-a-century. From 1858 to 1898—the period of Mr. Wallis's chairmanship—the undertaking had developed enormously. Mr. Wallis was succeeded by Dr. J. F. Armstrong, J.P., as Chairman.

In pursuance of the Board's progressive policy, and in order to encourage the use of gas, the prepayment meter system was introduced in 1900. Its inauguration manifested success from the beginning, and it eventually proved very popular. During that year Mr. Warner resigned from the position of Engineer, and was succeeded by Mr. T. H. Duxbury.

At the close of 1903 the various developments had resulted in the capital expended reaching the sum of £357,297. The coal carbonized for the year totalled 49,041 tons, and the gas sales reached nearly 461 million c.ft. The consumers numbered 17,091, who were supplied through about 118 miles of mains; and in view of further necessary extensions in order to cope with the continuous demand for gas, the Directors were compelled to again seek further parliamentary powers. In 1904 a further Act was obtained, in which, in addition to reducing the standard price of gas to 3s. per 1000 c.ft. within the Boroughs of South Shields, Jarrow, and Hebburn, and also reducing the difference in the margin of gas supplied to outside areas from 9d. per 1000 c.ft. to not more than 4d. in excess of the price for the time being charged in the County Borough of South Shields, Borough of Jarrow, and the Urban District of Hebburn, an additional £150,000 capital was authorized as ordinary or preference stock. Loan capital authorized was also increased by £50,000, making the total authorized stock capital £441,500 and the total loan capital £142,995. At the end of 1904 the Company supplied 18,807 consumers, of whom 6991 were through prepayment meters. In order to define satisfactorily the Company's area at Hebburn, an agreement with the Newcastle-on-Tyne and Gateshead Gas Company was entered into; and a new boundary line of supply between the Companies was arranged and duly confirmed in the Act obtained during the year.

In order to maintain the Company's progressive policy, and more especially to exhibit to the public the many advantages and utilities of gas, the Directors, during 1909, opened showrooms at South Shields and Jarrow. In 1911, Dr. Armstrong died; and Sir James Readhead, Bart., J.P., became Chairman.

To cope with the continued increasing demand for gas, the Directors decided, during 1913, to extend and reconstruct the Jarrow Works. Additional land adjoining the Company's premises was purchased, and an extension of the carbonizing plant and other apparatus was carried out.

The gas consumption for the year 1913 amounted to 560 million c.ft.; and in 1918 the consumption had increased to 593 millions—the number of consumers having increased during the period mentioned from 32,677 to 34,848. At this juncture it was again necessary for the Directors to seek additional powers; and they obtained from Parliament the South Shields Gas Act, 1919, by which they were enabled to follow the worthy traditions of previous history, and maintain the progressive policy of the Company. Many important provisions were included in the new Act to bring the undertaking up to current statutory requirements.

In 1918 Mr. Duxbury, Engineer and General Manager, died; and Mr. Dugald Currie was appointed to succeed him.

In 1921, the Board of Trade issued to the Company an Order, under the provisions of the Gas Regulation Act, which, on its receipt by the Company, was immediately put into operation.

The Company's present area of supply covers 25 square miles, and comprises the County Borough of South Shields, the Borough of Jarrow, the Parishes of Boldon, Boldon Colliery, and portions of the Urban District of Hebburn, and also a portion of the Parish of Whitburn. In 1924, the sales of gas amounted to over 614 million c.ft.

Adjustable Hydraulic Main Arrangement.

A description is to be found in the issue of the "American Gas Journal" dated Sept. 26 of an arrangement of hydraulic main which is based on a vessel whose vertical position is adjustable, and which is placed near the main over the top of the retort bench. A connection between the adjustable vessel and the tar receiver permits an interchange of liquid between the receiver and the vessel on the principle of the syphon. During the charging of the retorts, the adjustable vessel, which is open on top, and has over it a loose cover, is raised by means of a pulley and windlass from the working floor to its high position. Consequently the contents of the vessel pass into the hydraulic main and cause a certain amount of liquid to flow over the edge of the latter, and out through the hydraulic main connection. Thus the tarry liquid which is collected during the gasification period is removed. When the vessel is empty, both arms of the syphon, as well as the rubber hose connection, are full of liquid. After the retorts have been charged, and the lids are closed, the vessel is lowered until it reaches its lowest position. When this happens, the syphon begins to work, and a certain amount of liquor is removed from the main, with the result that the end of the standpipe no longer dips into it. The dimensions of the apparatus are such that during the time the retort is being charged an amount of liquid is removed from the hydraulic main which corresponds to the production of tarry matter during gasification, with the result that at the termination of the discharge period the end of the standpipe will always be slightly above the level of the liquid in the main.

Selas Furnace Control.

Apparatus known as the "Unit Control," for gas-fired furnaces, which is made by the Selas Gas and Engineering Company, Ltd., of City Road, Manchester, forms the subject of an illustrated article in "Engineering." With gas-fired furnaces, a reducing, oxidizing, or neutral flame can be produced at will by varying the proportion of gas to air; and the rate of heating and temperature of the charge can be regulated to a nicety by increasing or diminishing the supply of combustible mixture. Such adjustments, however, require some skill and experience—especially when it is necessary to keep the chemical properties of the furnace atmosphere constant at different rates of combustion—and the adjustments, however carefully made, may be upset by any material variation in the pressure of the gas, or of the air when this is supplied under pressure. The Selas apparatus has been successfully applied to carrying out these adjustments automatically and independently of pressure variations; and our contemporary illustrates an installation in connection with a heat treatment furnace in a Sheffield steel works, using producer gas having a calorific value of 150 B.Th.U. It may be explained that the functioning of the apparatus depends upon the differences in pressure between the inlets and throats of Venturi tubes, through which the gas and air are flowing; but the fact that these pressure differences are only very slight when the flow is reduced, renders it necessary to employ a sensitive relay for the actual operation of the control valve. The form of relay used in the Selas apparatus, it is stated, can be relied upon to operate accurately any size of control valve from 1 p.ct. of the full-load flow up to the maximum. With the particular apparatus described in the article regulation is effected by controlling the air supply; but a similar arrangement is employed where it is more convenient to regulate the gas. The writer concludes: "The control system certainly appears to be capable of effecting a material economy in fuel consumption, and also of producing more uniform results under normal working conditions than are possible with ordinary hand regulation. There is also, of course, the additional advantage that the amount of attention required is greatly reduced with the 'Unit Control' system."

Midland Junior Gas Association.—Among the matter unfortunately crowded out of this issue is the report of the meeting of the Midland Junior Gas Association at which Mr. J. H. Gee, B.Sc., delivered his Presidential Address. It will appear next week.

LONDON AND SOUTHERN DISTRICT JUNIOR GAS ASSOCIATION.

Opening Meeting of New Session.

[The airy assumptions of those who make a political war-cry of "cheaper electricity" are shown to have little basis in fact when attacked from the common-sense point of view of Mr. W. L. Westbrook in his Presidential Address. In this he adds the ingredient of scientific reasoning to the bright dreams of the visionaries—with the inevitable result. Mr. Westbrook, who is on the distribution side of the gas industry, has something to say on the important question of ventilation, remarking that the disappearance of the old-fashioned coal range has too often synchronized with the elimination of the kitchen chimney. The value of adequate welfare arrangements in promoting the efficiency of the workers is also stressed. Money wisely spent in this direction is, he maintains, an excellent investment.]

On Friday, Oct. 30, at the Westminster Technical Institute, the Association held their first meeting of the 1925-26 session. The meeting was attended by a very large number of the members, who came to welcome their new President, Mr. W. L. Westbrook, of the North Middlesex Gas Company, and to hear his address. At the outset Mr. W. NEWTON BOOTH, B.Sc., the retiring President, occupied the chair.

After the minutes of the last meeting had been read,

Mr. NEWTON BOOTH remarked that his last duty as President was to vacate the chair in favour of Mr. Westbrook, who was well known to all the members and had done a great deal of valuable work for the Association. After a succession of what might be termed works men, by electing Mr. Westbrook as President, who was engaged on the distribution side of the industry, they had done something to restore the balance. He hoped this would lead to a greater realization of the importance of the distribution and sales side of gas undertakings. The engineer's endeavour to effect economy in the manufacture of gas, and ensure that it was of constant quality and sufficient in quantity, represented only one-half of the activities of a gas concern. After the gas had been made, it had to be sold. Mr. Westbrook, it was interesting to note, was the third representative of the North Middlesex Gas Company who had been elected to the presidential chair of the Association during the past twelve years. This reflected great credit on the staff of that Company, and also on those who were responsible for their appointment. Mr. Newton Booth concluded his remarks by urging all the members to give to their new President that measure of support which had made his own year of office such a pleasant one.

Mr. WESTBROOK then took the chair, amid applause, and proceeded to deliver his

PRESIDENTIAL ADDRESS.

I thank you for the honour you have conferred upon me by electing me as your President for the coming session, and trust that with your full support and the loyal co-operation of the officers and members of the Council I may prove worthy of your confidence. It will be my constant endeavour to uphold the traditions of the Association, though I feel it is not going to be easy to maintain the high standard set by the able gentlemen who have previously occupied the chair.

Having always been engaged on the distribution and sales side of the industry, my address will be chiefly on distribution topics; but I hope members on the manufacturing side will not find it uninteresting. We are all members of one great industry; and in these days of keen competition, when politicians are calling for cheaper electricity and the extension of its use for domestic purposes, and the Government are talking of subsidizing our principal competitor, it is up to us, one and all, to put our backs into it, and, by close co-operation and up-to-date methods, both on our works and districts, to convince the public that gas is still the cheapest and best for light, heat, and power.

We should also take every opportunity of informing the public that, despite the window-dressing speeches of politicians, and their promises of cheap electrical power and consequent trade revival, it is not in the national interest to subsidize the generation of electricity. Even in super-power stations they can only claim at the outside an over-all efficiency of 20 p.ct., whereas, by the carbonization of coal in gas-works, and the recovery of the coke and other bye-products, over 80 p.ct. of the original energy in the coal is made available for the use of the community. Incidentally, by using gaseous fuel, they are assisting in smoke abatement; and that means a healthier community.

The following is an abstract from the Prime Minister's address to the University Conservative Association at Oxford on May 15 last, as reported in the "Daily Mail" of Saturday, May 16. Speaking on the question of cheaper electricity, he said:

> "I appointed, as soon as I came into power, an expert Committee, men of vision and imagination; and they have been working for many months to bring out a scheme for our consideration, dealing with this subject. Their report is now complete. The result of their deliberations will have to be examined most carefully by the Cabinet; and if the result of that examination should be that the Cabinet endorses their policy, the carrying out of that policy will be the first and most important task which the House of Commons will have to face on their re-assembling in the autumn."

Commenting on the proposed scheme in the same issue, under the heading "Cheaper Power for Industry," the Political Correspondent of the "Daily Mail" states:

> "The scheme provides for the compulsory grouping of all the electrical undertakings in the country into areas, the reduction of the number of small power stations and their replacement by a lesser number of super-power stations, linked and interlinked by power cables, with feeder cables running out to serve all parts of the country.
>
> "*Electricity Bonds.*—Heavy capital charges will be involved in the first instance, and it will probably be proposed that the Government should make an issue of Electricity Bonds, bearing interest guaranteed by the Government, in which existing electrical undertakings will be required to participate. Legislation to give effect to such proposals must be highly contentious, since many vested interests will be affected, and the compulsory powers with which the Electricity Commissioners will have to be vested will appear somewhat socialistic to die-hard conservatives. None the less, the Government thinks very highly of the prospects for lowering the costs of production by the supply of abundant electricity at a very low cost to the consumer. A vital factor in lowering cost is the maintenance of a high and steady load on the power stations. *This can only be achieved by popularizing the use of electricity in the home for domestic use.* A Committee appointed by the Electricity Commissioners is now considering further steps in this direction."

This is the proposition which is facing the gas industry. The case from our point of view has been ably stated by Mr. Milne Watson and other gentlemen; but it should be broadcasted and driven home. It would appear that the Government do intend to find money for cheap electricity. Many of the electrical undertakings are the property of the ratepayers, most of whom are also gas consumers. These undertakings, with others, will be compelled to take up shares, the interest on which the Government guarantee. Should the electricity be sold too cheaply, and the super-power station scheme show an adverse balance, I presume that the Government will then take the money out of the "left" pocket of the shareholders in the shape of taxes, and return it for them to place in the right pocket, as interest on a profitable investment. I am wondering if this is where the Premier's idea of "men of vision and imagination" comes in.

In reference to the above statement by the Political Correspondent of the "Daily Mail" that a high and steady load can only be obtained by popularizing the use of electricity in the home for domestic purposes, I think that is where we (the gas industry) say, "What we have we hold." At any rate, it will have to be really cheap electricity to beat us.

Take water heating for bath purposes. By means of a geyser, which is perhaps our most efficient service, we can provide 25 gallons of water raised 56° Fahr. at the spout of the geyser—say, from 50° Fahr. cold to 106° Fahr. (hot bath temperature)—at an expenditure of 35 c.ft. of 500 B.Th.U. gas, equal to 17,500 B.Th.U. (allowing 80 p.ct. efficiency for the geyser), and costing, at 10d. per therm, 1¾d. The same service, at the same cost, by electricity (allowing 90 p.ct efficiency for the electric heater) would require the dissipation of 4½ units, which would have to be sold at 0·39d. per unit.

For heating, 100 c.ft. of 500 B.Th.U. gas consumed in a gas fire, allowing 70 p.ct. efficiency for the fire, would provide 35,000 effective B.Th.U. To provide the same service by electricity, allowing the full 100 p.ct. efficiency for the fire, would require 10·23 units at a price of 0·49d.—less than ½d. per unit. Even assuming that electricity could be profitably distributed at ½d. per unit, there would still be, from the national point of view, the recovery of the valuable bye-products to take into account.

While the figures I have given show that the advocates of electricity for domestic purposes have a long way to go, the aim and slogan of the gas industry should be "a plentiful supply of cheap gas." Gas is such a convenient and efficient fuel that, provided it can be supplied cheaply, we need have no fear of competition or subsidies. It is, therefore, I repeat, up to one and all to strive for the highest efficiency, and, by up-to-date methods and the elimination of waste, to place the industry in an unassailable position.

I now want to say a few words with reference to education and training, particularly from the distribution and sales point of view. For many years I have been keenly interested in technical education as applicable to our industry, and as a local examiner in gasfitting have some slight knowledge of the results obtained. Ten or twelve years ago, classes in gas supply, outside London, Birmingham, and a few other centres, were practically unobtainable, as was also advice as to the most useful ancillary subjects to study. This has all been altered. Thanks to the efforts of the Institution of Gas Engineers (and, as we are proud to state, the representatives of the Junior Associations), classes are now available in numerous centres, affording the young men of to-day the opportunity of obtaining

the necessary knowledge, if they are ambitious to rise in their profession. As Secretary of the Institution Education Scheme we have Mr. Walter Hole, whose name and work should be an inspiration to all distribution men.

As far as the education of gasfitters is concerned, past experience has shown that a great many were very weak on the theoretical side, or were lacking in the power of expression. The introduction of the grouped courses should do much to remedy this weakness, though I cannot help feeling that perhaps more care is required generally throughout the industry when engaging lads, and that a higher standard of general education is desirable. With the introduction of the Institution Scheme and the Diploma Course, the way is now open for young men on both the engineering and the sales sides of the industry to equip themselves for the highest positions attainable; and this brings me to a point to which I particularly want to direct attention. While the embryo gas engineer is duly articled and specially trained for his profession, by being taken through the various departments until he is qualified to take a post as assistant engineer, the distribution expert, like the proverbial waif, "seems to have just growed."

I suggest that the time is ripe to supplement the Education Scheme by giving men of suitable education a definite training for the important posts of distribution engineers and sales managers (or whatever other titles you may elect to bestow on them). No doubt the system of "letting them grow" will in most cases bring the industrious and pushing men to the top; but, when you consider the ramifications of the distribution and sale of gas, and the qualifications necessary to control and direct such a business efficiently, I think you will agree that men should be specially trained for that purpose. At the present time, some undertakings have as their chief distribution officer a man whose training was principally on the practical side and whose commercial and administrative experience had to be acquired subsequently; in other cases we find an official in charge with little or no practical experience. Undoubtedly this is a handicap and drawback, as really practical experience cannot afterwards be fully acquired, and its absence is apt to engender a certain contempt in those under his control—particularly if they are up against a difficult proposition, and are unable to obtain the necessary help and guidance from their chief.

I want to say a few words with reference to welfare arrangements. The importance of good well-cooked food, congenial surroundings, and healthy recreation in maintaining and increasing the efficiency of the workers, whether by brain or brawn, cannot be over-rated; and money wisely spent with this object in view is an excellent investment. In this direction my Company have provided at Mill Hill a well-equipped canteen where a well-cooked dinner comprising a cut from the joint with two vegetables and pudding is provided for 1s. The interior of the canteen is white tiled, the floor, tables, and counter are of granolithic, so that perfect cleanliness is easily maintained. The canteen is equipped with gas cooker, copper, hot closet, and carving table; and a plentiful service of hot water from a Potterton apparatus comprising a 50-gallon lagged cylinder with cut-out valve, heated by three No. 20 Victor boilers, is available. This apparatus is fixed in the spacious wash-house under the canteen, and also serves the range of lavatory basins, showers, and baths with which the wash-house is equipped. The wash-house is also finished inside from floor to ceiling with white tiles; the floor being of granolithic. The blocks used in the construction of the building were all made on the works. Open-type steel lockers are provided for the men, who are thus able to wash, and change their clothes before leaving the works. There is also a Social and Athletic Association, comprising football, cricket, tennis, and social sections; a spacious football and cricket ground with pavilion; a hard court for tennis; and a co-partners' club room—all provided by the Company. The co-partners' club room contains a full-size and a quarter-size billiard table; and competitions in billiards, ping-pong, chess, and draughts, also whist drives and dances, are arranged—chiefly, of course, during the winter months. There is no doubt whatever that the efforts of the Company to promote the welfare and provide for the recreation of their employees are highly appreciated by the men, and promote an excellent *esprit de corps*.

Turning to more technical topics, there is one field in which I fear we are not as well equipped as we might be in meeting the competitive challenge of our electrical friends. I refer to the problem of heating small rooms or apartments that are without a chimney or flue. As far as I can judge, the question of the use of flueless stoves is one on which the various gas undertakings have no definite universal policy. Some undertakings condemn the use of flueless stoves in living rooms and bedrooms altogether, while others exhibit such flueless heaters as "Kern" radiators in their showrooms, and presumably fit them in approved positions. I suggest that it would be helpful if the question of the maximum amount of gas that could safely be burned per hour in rooms without a chimney and without special ventilation arrangements—say, from 500 c.ft. capacity upwards—could be definitely fixed. Flueless stoves should then be plainly labelled, showing their consumptions per hour, and fitted with approved governors to prevent the rated consumption being exceeded. In my Company's area a large number of houses are being built with one or two small bedrooms without chimneys. Unless suitable gas stoves can be fitted in rooms of this description, electric radiators will be installed; and I submit that we cannot afford to risk the loss of this business.

The question of flues and ventilation is of vital importance to the gas industry; and if the progress made in gaseous heating is to be maintained, an effort must be made to secure an improvement over the present inadequate and haphazard arrangements. At the root of the trouble lies the question of £ s. d. The speculating builder is so keen on cutting costs that he is tempted to leave-out flues and ventilating arrangements whenever the bye-laws will allow him to do so. The campaign of the gas cooker and coke boiler against the coal range has resulted in the absolute rout of the latter; but unfortunately, with the disappearance of the coal range in the modern house, the kitchen chimney is in many cases also missing. This should not be allowed, as the removal of the products of combustion and greasy vapours from a gas cooker is important from the point of view of health and hygiene. In many cases, in addition to the gas cooker, there is also installed a gas copper for which no proper ventilation arrangements are available. Building bye-laws should make the provision of a proper chimney for the ventilation of cooking and heating apparatus, of whatever description, compulsory. Living rooms and bedrooms should perforce be provided with a chimney; while the extending popularity of the geyser as a bath heater, and the extreme importance of perfect ventilation where such apparatus is likely to be fixed, should justify the demand for a chimney in every bathroom. All this may sound like a tall order; but, given cheap gas, there will be such a demand for our labour-saving commodity that architects and builders will be only too ready to make proper provision for the installation of appliances.

Economy Flues.

The introduction of the "Nautilus" type of flue has been of considerable assistance in obtaining installations of gas fires, but, unfortunately, the down-draught troubles that have arisen (due to wind pressure) through the practice of terminating these flues under the eaves, has done much to discredit the system and check development. The flues should, in every case, be carried-up, and terminate above the ridge of the roof. There have also been a very large number of flues built in the cavities of walls, and, in addition to terminating under the eaves, these have often been so carelessly constructed that there has been practically no free passage through them; mortar from the joints being allowed to collect, and block the flue-way. I am certainly in favour of smoke abatement; but when one comes across these ventilating monstrosities, the thought arises that there are disadvantages even to a smokeless fuel.

As soon as we had an opportunity of testing gas flues with eaves terminals, and found them defective, we immediately wrote to all local builders pointing out the trouble, and advising them to extend the flues and terminate them above the roof. We also stated that the Company reserved the right to refuse to connect fires where the flues terminated at the eaves. In some cases this had the desired effect, but I am sorry to say that in the absence of preventive bye-laws, the practice still continues to some extent, and builders have themselves fitted fires where the Company refused to connect. Some of these fires have since been removed by the Company at the request of the consumers.

Every district man should take a keen interest in this problem of ventilation; and I suggest that the subject is of sufficient importance to receive the attention of the National Gas Council, with a view to the framing of suitable bye-laws covering the ventilation of gas appliances. My Company are at present seeking powers to control the quality of all fittings fixed in their area, and to issue a specification for carcassing new buildings.

In conclusion, I make an appeal to all members to give full support to the Association during the session by attendance at meetings as well as visits to works. Let us have full and free discussions with friendly constructive criticism. The London and Southern District Junior Gas Association is the largest of the English Junior Associations; and London should lead.

Mr. A. Broadbent proposed, and Mr. Leonard Lacey seconded, a vote of thanks to Mr. Westbrook for his interesting address.

The Chairman, after thanking the members for the hearty way in which they had received his address, said that the Association were honoured by having with them Mr. Stephen Lacey, Distribution Engineer of the Gas Light and Coke Company, who would perhaps say a few words.

Mr. Stephen Lacey remarked that the Association had every reason to be proud of its past and hopeful for its future. Certainly he would do everything he could to further its aims. As they probably know, he was Chairman of the London Area Gas Salesmen's Circle. Some might ask whether there was room for both. He would say without hesitation that there was ample room. If the same subjects were from time to time taken for discussion, it must be remembered that they would be attacked from different points of view. The Junior Associations would deal with them from a technical aspect, and

the Salesmen's Circles from the viewpoint of the consumer. After observing that Mr. Westbrook took a keen interest in the London Salesmen's Circle, Mr. Lacey concluded his remarks by wishing the Association a valuable and enjoyable session.

PRESENTATIONS.

The CHAIRMAN said that he had now to perform the first real duty of his office. This was a very pleasant one—that of expressing the thanks of the Association to Mr. Newton Booth, not only for his work as President during the past session, but on account of his valuable help for many years prior to this, both as an ordinary member and as a member of Council. He would ask Mr. Newton Booth to accept an illuminated address as a tangible mark of their appreciation. He would also ask Mr. Broadbent to accept an illuminated address, as a recognition on the part of the Association of his valuable work as Treasurer for five years. Mr. Westbrook said that he had to make a third presentation—again in the form of an illuminated address—to Mr. Leonard Lacey, who for two years had taken upon himself the hard task of Hon. Secretary.

After Mr. NEWTON BOOTH, Mr. BROADBENT, and Mr. LACEY had expressed their thanks to the Association,

The CHAIRMAN announced that he had received letters from Mr. F. W. Cross, of Lea Bridge, Mr. S. B. Chandler, of Tottenham, and Mr. W. J. Sandeman, of Croydon, in which they regretted their inability to be present at the meeting.

Mr. NEWTON BOOTH then moved a proposition that the Association, through their Hon. Secretary, should communicate with the National Gas Council with a view to the Council framing suitable by-laws covering the ventilation of gas appliances, as suggested in Mr. Westbrook's address.

Mr. L. LARKIN (Gas Light and Coke Company) seconded the motion, which, on being put to the meeting, was carried unanimously.

YORKSHIRE JUNIOR GAS ASSOCIATION.

Annual Meeting.

[Features of this meeting were references to the appeal of the Leeds University (warmly supported), and a paper by Dr. E. W. Smith, in which he stressed the importance of properly preparing coke for domestic consumption.]

The Twenty-Second Annual Meeting of the Yorkshire Junior Gas Association was held on Oct. 24, in the Lecture Hall of the Fuel Department, Leeds University. The PRESIDENT (Mr. E. Gillett, of Bradford) occupied the chair, and there was a very good attendance. Visitors included Mr. W. B. McLusky, Halifax Borough Gas Engineer and General Manager, and representative of the Manchester Institution on the Yorkshire Junior Association Council; Prof. J. W. Cobb, Fuel Department, Leeds University; Dr. Hodsman, Dr. Parker, and Mr. J. W. Wood, of the same department; Mr. J. H. Brearley, formerly Engineer at Longwood and now of Southport; Dr. E. W. Smith, Technical Director of the Woodall-Duckham Companies, London; and Mr. F. A. C. Pykett, of Lancaster (representing the Manchester Junior Association).

Mr. J. B. BALMFORTH (Bingley) asked whether the Council had come to any decision on a suggestion he had raised last year as to the possibilities of making a grant from the Association funds to the Benevolent Fund of the Institution of Gas Engineers.

The PRESIDENT replied that the Council had considered the suggestion very carefully; but in view of the slow—but fortunately now steady—building up of the Association's funds, and a feeling expressed sometimes that there should be some reduction in members' subscriptions, it had been felt that for the present it would be inadvisable to make such a grant, and better to wait until the finances were stronger.

REPORT AND ACCOUNTS.

The annual report was presented by the HON. SECRETARY (Mr. J. W. Horwill, of Bradford). It stated that the membership of the Association totalled 171.

The HON. TREASURER (Mr. H. Wilde, of Bradford) submitted the annual statement of accounts, which showed a credit balance of £99 7s. 10d.

Mr. F. CLEGG (Huddersfield), moving the adoption of the report and accounts, remarked that the finances were looking much more healthy than some time ago; and he hoped it would not be long before the Council were in a position to consider again the suggestion of a contribution to the Institution Benevolent Fund. Another opportunity for the Association to show its gratitude for benefits received had arisen lately in the appeal of the Leeds University on behalf of the extension fund. The Association owed a very great debt of gratitude to the Leeds University for facilities and help given throughout the Association's existence.

Mr. H. RHODES (Bradford) seconded the motion.

Mr. P. M'NAB (Low Moor) said Mr. Clegg had raised a matter—the appeal of the Leeds University—which he had himself asked should be put on the agenda for that meeting, with a view to a definite proposition that a contribution be made.

The SECRETARY said the appeal had come before the Council, and was down for consideration later in that meeting.

Mr. J. H. BREARLEY (Southport), as one who had been in some degree connected with the earliest days of the Association, remarked that he was delighted to have the opportunity of being present at the completion of the 21st year, and to congratulate the Association on its growth and success.

The report and accounts were then adopted.

NEW OFFICERS.

The election of officers for the coming year resulted as follows:

President.—Mr. R. N. Webb, New Wortley Gas-Works, Leeds.

Senior Vice-President.—Mr. S. T. S. Musgrove, Sheffield.

Junior Vice-President.—Mr. C. H. Chester, Wakefield.

Hon. Treasurer.—Mr. H. Wilde, Bradford.

Hon. Secretary.—Mr. J. W. Horwill, Bradford.

Assistant Hon. Secretary.—Mr. F. Firth, Leeds.

Added to Council.—Messrs. W. Heathcote (Halifax) and C. T. B. Roper (Bradford).

Auditors.—Messrs. A. W. Arnold (Bradford) and A. Lister (Yeadon).

PRESENTATION TO RETIRING PRESIDENT.

The PRESIDENT, introducing Mr. R. N. Webb to the chair, said that gentleman had been connected with the Association throughout, and had rendered valuable service in many ways and for many years.

Mr. WEBB thanked the members for the honour done him, and then, on behalf of the members, presented to Mr. Gillett, the retiring President, an enamelled gold medallion, suitably inscribed, to mark the completion of 21 years' existence of the Association, and also of 21 years' active connection of Mr. Gillett with it. Curiously enough, said Mr. Webb, the occasion also marked the 21st anniversary of his own connection with the Association, and it happened also to be his 21st year of association with the New Wortley Gas-Works at Leeds. One thing which to his mind had been of great value in all their organizations was the openness of discussion and exchange of information. The industry was one of the most open and candid of any industry he knew. It was through this fraternity that the industry was being kept so much alive as it was to-day—more alive than ever it had been; and it was going to be still more alive.

Mr. GILLETT, expressing his appreciation of the gift, said he was very glad Mr. Brearley was present that day; for he remembered that the start of the Association, from Mr. Cranfield's class, really arose out of a visit to the Longwood Gas-Works, then in Mr. Brearley's charge.

A vote of thanks to the retiring officers and members of Council was carried, on the motion of Mr. A. WYLIE (Sheffield), seconded by Mr. J. E. HALLIDAY (Otley).

COKE FOR DOMESTIC PURPOSES.

Dr. E. W. SMITH (Technical Director, the Woodall-Duckham Companies) then delivered an address on the subject of "Coke for Domestic Purposes." He took as his text the introduction to the contribution which the Research Section of the Woodall-Duckham Companies made to the recent Coke Competition, organized by the "GAS JOURNAL."

During recent times, he said, it had been realized that the price of gas depended largely on the average price received for coke. Coke had been the Cinderella of the gas industry; it still was so in many cases. Not only should the coke market be developed because of its effect on the price of gas, but in developing the coke market they were also assisting to cure the smoke nuisance. Unfortunately, there were still many engineers who were not convinced that coke was worth bothering about. There were not many such representative of the Junior Gas Associations.

A great deal could be done by all gas-works to make coke more suitable for domestic purposes. Dry coke, properly graded, was a great deal more satisfactory than wet coke ungraded. After everything had been accomplished in this way, there was room for much more to be done in the direction of blending coals, and modified carbonization methods, with a view to producing free-burning smokeless fuel, equal to the best that had ever been made at low temperatures. The sole object of the recent Coke Competition was to encourage a greater study of the subject; and the results, he suggested, had fully justified the competition.

One thing he feared was that, with the recovery of trade, gas engineers would lose the interest that was being developed in connection with coke. It had always been so; but he did sincerely hope that, with a proper study of this subject, interest would be maintained. It was for the industry to create a

market which would be permanent, and could be relied upon; a market which would be independent of change in general industrial conditions, and dependent only on the fact that people had to have heat for domestic purposes, and that this heat could best be supplied by gas and by coke.

Referring to the appeal of the Leeds University, Dr. Smith said he regarded the real beginnings of organized technical work for the gas industry as having emanated from Leeds University. He indicated that the first joint work arose from a suggestion of Mr. J. H. Brearley, in connection with his experimental work on gas fires. He doubted whether the country, or even Yorkshire itself, quite appreciated how much the gas industry owed to Leeds University. Most of the important lines of development, in recent years, of a technical nature had been anticipated by the Fuel Department at Leeds—gas fires, continuous carbonization, water gas, waste-heat boilers—and it was on record that Sir George Beilby would have found it next to impossible, in the time, to prepare his recommendations for the Gas Regulation Act, if he had not had the facilities of basing his conclusions on the valuable work carried out for the Gas Investigation Committee by Mr. Wood.

Leeds was also responsible for the joint research work for the National Benzole Association; and their conclusions had all been sound, whatever subject they had dealt with. None had been rebutted; and he was delighted to learn that the energies of the Research Staff had now been switched on to the study of coke. His Company had for three years been working on this subject, and had been in close touch with various authorities—such as Mr. E. C. Evans, Mr. E. V. Evans, Mr. John Roberts, and others—and all he could say was that the results of such co-ordinated knowledge were entirely available for the Research Department of the Leeds University.

Fundamental research work required to be done, and this could only be carried out by such an organization as Leeds University. He was quite satisfied that, in spite of all that had been done, Leeds was willing, and able, to absorb still more work, if the necessary financial backing were provided; and he suggested that every pound given to Leeds University for research work would bring back to the gas industry £100, or even £1000, in return.

Discussion.

Mr. W. B. McLUSKY (Halifax), proposing a vote of thanks to Dr. Smith, said he had been interested for a long time in coke. During the period of stress, when coke could fetch high prices, it had cost his department a good deal because they chose to keep the coke for their own use. They were reaping the benefit now. There were people, he knew, who must have a coke that was compressed; but he believed in most towns the larger demand was for the porous fuel from the continuous vertical retort. This was very light, and in the domestic grate burned like wood. He would say: "Do not dump." It was better to cultivate the home market. There was a great and growing demand for coke fuel; but the public had not yet been educated in the matter of making a selection of the kind of coke required for their particular purpose. In his own district there was coke, produced elsewhere, being sold at a lower price than that from the Halifax Gas-Works, but it was of such an inferior quality that, despite the lower price, it did not affect the demand for the Halifax coke. At the same time, he thought there was a danger in allowing such fuel to come into a town whose local gas authority were producing a good coke. It was the duty of every gas engineer to realize that it was not fair competition to send anything inferior, and at a lower price, into the area of another gas undertaking. In vertical retorts it was possible to over-steam, and thereby produce a coke that was not suitable. In regard to grading of coke, he had found that double screening was desirable. Single screening was all right for large coke; but for the smaller coke all the fuel should be double screened, with such an orifice in the mesh that every piece would be a cube. If they were selling half-inch coke, it should be half-inch every way.

Mr. J. LISTER COOPER (Yeadon), seconding, said it was only by cultivating the domestic use of coke that a real outlet could be secured for increased consumption. It was certainly necessary that the coke should be of proper constitution and proper grading. Some time ago he had introduced at his works a coke breaking, screening, and washing plant, to encourage a market for washed coke, which was used largely in his district for industrial furnace hearths; and there was a fairly good sale. The chief problem of the gas undertaking was, of course, to sell cheap gas: but no undertaking could sell gas as cheaply as it ought, if it did not make the most of its coke and other products. He was sanguine enough to believe that in a few years' time all domestic heating would be either by gas or by coke. He had heard some time ago of a test made by a laundry undertaking as between "Coalite" and coke. The "Coalite" worked out at about 9 p.ct. greater heating efficiency than the coke, but the cost was 25 p.ct. more.

The PRESIDENT said it had occurred to him that the subject raised by Dr. Smith was well worth an entire meeting for discussion; and it would be a great benefit and pleasure if they could get Dr. Smith to come again, during the session, and give it a start. There were more ways of using coke than one, not only in household fires, but in their own gas-works.

Mr. J. H. BREARLEY (Southport) said he could endorse everything Dr. Smith had said about coke, as well as his remarks about the work of the Leeds University. Dr. Smith, however, had omitted to give Leeds University credit for its moulding of many fine men who had contributed so much to the gas industry, and among whom was Dr. Smith himself. Dr. Smith had come to Leeds to undertake research work on gas-fires; and he was proud to feel that he had been associated for some few years with Dr. Smith in this work. It was from the time of that investigation at Leeds, he supposed, that research conducted by makers of gas fires really dated. He hoped the appeal of the Leeds University would not flag. It had certainly been given a fine start; and he hoped the gas industry in general would follow the excellent lead given by the South Metropolitan Gas Company in supporting the appeal.

Dr. SMITH, replying to the vote of thanks, said he was not particularly pushing the use of vertical retorts. Any installation could make a perfectly satisfactory coke for domestic uses if people would get down to the task; and he was quite prepared to give all assistance in his power to any installation to produce a good coke that would sell for household purposes. The first essential was that the coke should be dry, and the second that it should be properly graded. They wanted, then, a free-burning smokeless fuel—and this was where they still needed further research—a coke which would be as dense as a coke-oven coke, but as porous as charcoal. This, he was convinced, could be made. The point he wanted strongly to make was that the future of the cost of gas was, with the assistance of a coke market properly used, very alluring.

THANKS TO LEEDS UNIVERSITY.

Mr. E. J. SUTCLIFFE (Bradford) moved a hearty vote of thanks to the authorities of the Leeds University, and to Prof. Cobb, for the facilities and help extended to the Association for so many years past, and referred to the many kindnesses shown the Association by Prof. Smithells, Prof. Cobb, and the members of their staffs, right from the beginning of the Association's activities. While on the subject of the Leeds University, he wished formally to move a rider that, as a mark of the Association's appreciation, the Council be instructed to consider the question of a grant in response to the University's development fund appeal, and that such contribution be as generous as the Association could afford.

Mr. F. LODGE (Wakefield), seconding, said he entirely endorsed Mr. Sutcliffe's observations. He believed every member realized the immense value of the services of the Leeds University to the gas industry.

The PRESIDENT was glad this matter of the University's appeal had been brought forward, and gave the assurance that the Council would pay the most serious attention to the matter. [Applause.]

Prof. COBB, responding, said the University was always pleased to be of any assistance in its power, and was glad the Yorkshire Juniors continued to visit it. He was grateful for the spontaneous manner in which the meeting had accepted the suggestion that a donation should be made to the University's development fund appeal. He would like to endorse everything Dr. Smith had said as to the importance to the gas industry of the close study of coke. The public conscience was rapidly being roused as to the importance of removing the disgraceful smoke pall hanging over industrial districts. This task was being partly accomplished by gas, but there was no doubt it must be followed up by the greater use of solid smokeless fuel; and there was a great opportunity for the gas industry to see that it was the operative agent in the work of replacing the burning of raw coal. Dr. Smith had made mention of Mr. Brearley's initiative in the matter of the beginnings of research in gas fires. They of the Leeds University were fully conscious of this; and he was delighted Mr. Brearley was with them that day, so that they could renew acquaintanceship with him. Since this early research—in regard to which much tribute must be paid to the work of Dr. Smith himself—research in the gas industry had extended and developed, and with it there had been a rapidly growing development of the Leeds University in that direction. The appeal lately issued by the University was very largely an appeal for increased accommodation. If they took the case of that department alone, they would realize how the appeal had become necessary. When Mr. Hodsman came to Leeds he (Prof. Cobb) and Mr. Hodsman were the entire staff of the Department. Now the staff comprised the two of them; but also engaged in the co-operative research work of the gas industry were Mr. Wood and Dr. Parker, to the value of whose work Dr. Smith had borne testimony, and three other members. In addition to this was the further development, typical of the times, which had come in the direction of the benzole research, in the initiation of which Dr. Smith played a very prominent part. He ought to refer, also, to the steady stream of research work carried out by a succession of Research Fellows, who, after building-up research at Leeds, had gone out to responsible posts in the gas industry to continue their valuable work there. The first of these was Mr. Hollings, now Chief Chemist to the Gas Light and Coke Company. There were others, whose services to the gas industry were becoming more pronounced every day. He wanted to acknowledge the generosity of the University in providing him with a very highly qualified Research Assistant in Mr. Holdsworth, especially on the subject of refractory materials, a matter which was of primary importance to the gas industry. They had also now a special member of the staff devoting all his time to metallurgy.

After the meeting the members adjourned to the Griffin Hotel for high tea, which was followed by an enjoyable smok-

ing concert. Mr. Webb was in the chair, and announced that Dr. Smith had consented to visit the Association on Jan. 16 to open a discussion on the subject of coke. That meeting, by generous agreement of Mr. McLusky, would take place at Halifax. In the course of the evening a toast was given by the President to "Kindred Associations," to which Mr. F. A. C. Pykett responded, particularly as representing the Manchester Junior Gas Association. Mr. W. B. McLusky conveyed the greetings of the Scottish Eastern District Association, which he had recently visited, to the Yorkshire Association.

THERMAL DECOMPOSITION OF ETHANE.

A paper by A. Williams-Gardner, published in the October issue of "Fuel in Science and Practice," gives a preliminary account of the initial stages of a research on the cracking of paraffins, which has begun with a study of the thermal decomposition of ethane. The following tentative explanation of the behaviour of ethane at different temperatures is formulated.

Under conditions of pressure slightly lower than normal, ethane first shows signs of decomposition at 550° C. Decomposition is, however, very slow, and secondary changes are unlikely to occur at so low a temperature as this. The main products of the decomposition are methane and ethylene, with traces of hydrogen. At slightly higher temperatures the ethylene shows a tendency to be hydrogenized by the hydrogen present, yielding methane, at the same time undergoing slight decomposition into carbon and hydrogen. The intermediate formation of acetylene is extremely doubtful. Moreover, at no period during the thermal decomposition of ethane does acetylene make its appearance as such in any appreciable quantity, nor does it play an important part in the different reactions taking place at any temperature.

Up to 800° C. conditions favour the formation of liquid products; but above this temperature there is a strong tendency for ethane and ethylene to decompose to their elements, and at the same time be hydrogenized to methane. At still higher temperatures, the decomposition of methane sets in.

Contrary to the experience of Bone and Coward, aromatic compounds were found to be formed in appreciable quantities. Benzene is one of the chief liquid products. This formation of aromatic bodies is to be ascribed essentially to the behaviour of ethylene at certain temperatures in the region of 750° C. At these temperatures, the predominant secondary change would appear to be the polymerization of an unsaturated body, with elimination of hydrogen. The mechanism of the changes occurring can be explained on the assumption that there is a scission of the C-C bond in the ethane molecule, giving rise to $.CH_3$ residues which are stable at temperatures in the region of 550° C. With rise in temperature, however, these residues become dissociated to the more unsaturated, and possibly less stable, $:CH_2$ residues, which form the equilibrium mixtures with ethylene; hydrogen at the same time being eliminated. With rise in temperature, $.CH_3$ groups are hydrogenated to methane, while the $C_2H_4 \rightleftharpoons :CH_2 + :CH_2$ reaction proceeds away from the ethylene side; the $:CH_2$ residues undergoing: (*a*) Decomposition into $\vdots CH$ residues and hydrogen, the former polymerizing to liquid products or decomposing into carbon and hydrogen; (*b*) hydrogenation to methane; or (*c*) direct decomposition to carbon and hydrogen. The residues $\vdots CH$ may be considered to have more than the "fugitive separate existence" attributed to them by Bone and Coward.

It appears, then, that the thermal decomposition of ethane depends on the decomposition of a paraffin to form a lower paraffin and an olefine. Subsequent changes may be ascribed to the secondary decomposition of the products. Thus, so far as ethane is concerned, the methane formed from it is stable at low temperatures, while the ethylene found shows at first a strong tendency to polymerize and dehydrogenate, and later suffers disruption of the molecule, yielding carbon, hydrogen, and some methane.

Small Industrial Uses of Gas.—To illustrate his contention that at least some small gas consumers may be made to pay their way very nicely, Mr. James R. Jennings, writing in the "Gas Age-Record," cites the modern soda fountain. He shows a picture of a new type of soda fountain, of a somewhat elaborate character, which, he says, is to be found in the business section of practically every locality in the towns of the United States. There was a time when this soda fountain offered nothing but ice cream and cold drinks; but now the greater share of its sales consists of sandwiches, coffee, hot chocolate, poached eggs, &c. Gas or electricity are the only fuels that can be used in this situation. Another direction is the gas-fired presser for tailors' use. These are, Mr. Jennings points out, only two of the many small users of gas who may be made profitable customers for the gas company. Any soda fountain or any tailor will use more gas in a month than any one domestic consumer. A survey of his area will show the commercial gas man untold opportunities for the introduction of gas into industries which he has never suspected.

A NEW YORK TESTING LABORATORY.

The Consolidated Gas Company of New York maintain an admirably equipped testing laboratory, which is directed by Mr. N. T. Sellman, Engineer of Utilization. It appears from an illustrated account which has been published by the "Gas Age-Record" that the laboratory occupies over 10,000 sq. ft. of space, and has a personnel of 25 men. Industrial and domestic appliance testing is divided into separate departments.

Thermal conductivity apparatus for the analysis of mixtures of gas and air was secured through the co-operation of the Bureau of Standards. There are two cells, one containing air at atmospheric pressure, and hermetically sealed; and the other the sample under analysis, which is drawn in by an aspirator. Stretched inside the cells are two fine platinum wires, one in each cell, which form two arms of a Wheatstone bridge. The resistance added to give a zero deflection to the galvanometer, with the use of a calibration curve, gives the air-gas ratio of the mixture. The calibration curve is secured by using the apparatus to analyze known mixtures of air and gas; and once the calibration curve is obtained, the determination of the air-gas ratio of the mixture can be carried out rapidly and accurately. The practical use of this apparatus is to measure the quantity of primary air that is being supplied to a burner. To do this, a small sample is taken from the inside of the burner while the burner is in operation.

There is an automatic carbon monoxide recorder, obtained from the Mines Safety Appliance Company, of Pittsburgh, through the co-operation of the Bureau of Mines, by whom it was developed. This comprises a cell and a flow meter; the cell containing an active chemical and a thermo-couple. The chemical, which is known as "Hopcalite," has for its purpose the catalytic oxidation of carbon monoxide, and generates heat according to the quantity of carbon monoxide present. The thermo-couple is connected to a recording potentiometer, registering in parts per million the carbon monoxide present in the sample. The flow meter is utilized to pass the sample through the "Hopcalite" at a uniform rate; and the carbon monoxide is recorded continuously on the chart in parts per million.

An air-tight room has a cubical content of approximately 1000 c.ft., and is built of steel, with a ventilating system having a water-sealed outlet. Air changes from 0 to 10 per hour can be obtained and accurately measured. This room enables the chemists to operate a gas appliance under the various conditions which are found in practice, and in conjunction with the carbon monoxide recorder has been found extremely valuable.

To determine small amounts of carbon monoxide, an iodine pentoxide apparatus is used. The action of carbon monoxide releases a proportional amount of free iodine, which is absorbed by potassium iodide; and the titrating of the potassium iodide with sodium thiosulphate gives the measurement sought for. Its use in this laboratory is practically limited to checking the results of the automatic carbon monoxide recorder. One check is taken for each appliance test.

By means of a Thomas recording calorimeter, a continuous record is furnished of the heating value of the gas which is used in the laboratory.

Mineralized Sawdust Concrete.

On Nov. 2, before the Society of Engineers, Mr. G. O. Case read a paper on this subject. As a result of experiments made by the author, a process known as the mineralization of sawdust was patented. This system, it is claimed, prevents contraction or expansion of the sawdust when mixed with cement and water, and at the same time renders it fireproof. In the paper mentioned a description is given of various tests made with mineralized sawdust and Portland cement to determine the tensile strength, resistance to abrasion, heat conductivity, absorption, contraction in setting, transverse bending, and the effect of freezing. As a result of these tests the following conclusions are arrived at: Wood flour in sawdust in any considerable quantity is detrimental to the tensile strength of the concrete. The compressive strength of concrete made with mineralized sawdust is lower than that of concrete made with sand and gravel aggregates, but is at the same time more than adequate for general use unless an exceptional compressive strength is required. When under compression the material does not disintegrate even when the maximum pressure has been reached. Concrete made with mineralized sawdust is more durable when subjected to severe wear, and is a better non-conductor of heat, than ordinary concrete. The paper concludes with a short summary of the general advantages of concrete made with mineralized sawdust. It can be nailed or screwed, sawn, and polished. It is light in weight, resilient, and less noisy to the tread than ordinary concrete. It is becoming more widely known as a precast unit for the construction of floors, pavings, &c.

CORRESPONDENCE.

[We are not responsible for opinions expressed by Correspondents.]

Coke for Domestic Stoves.

SIR,—Regarding your Coke Number, and the paragraph I notice in the current issue of the "JOURNAL" with reference to anthracite stoves, Mr. J. H. Chew, of Blackpool, was telling me that he had used coke in his anthracite stove for two years, and would not in any case return to anthracite. It was filled night and morning only, and required no other attention, and was never out from October until the end of March.

I was also struck with the coke type fire I observed at Wembley. Mr. Samuel Tagg, of Preston, I understand, has been testing one in his house, and is very pleased with the results.

Both these factors, I think, if exploited, would have considerable bearing upon the coke market.

JAS. W. SCOTT.

Gas Plant Works, Manchester, Oct. 29, 1925.

Lack of Science in the Gas Industry.

SIR,—I was acquainted with the paper on the Scunthorpe plant in the number of the "JOURNAL" to which you refer in your footnote to my letter in last week's issue. I was, however, led by the use of the term "a glorified Tully plant" to assume that Mr. Simpson did not refer to the design in the paper. Otherwise my criticism holds good; and it seems to me that, if the "Scunthorpe experiment" had succeeded, it would have necessitated the repudiation of the law of the conservation of energy. Thermal analysis would have led to this conclusion without experiment.

M. W. TRAVERS.

147, *Queen Victoria Street, E.C.* 4,
Oct. 31, 1925.

MISCELLANEOUS NEWS.

PORTSEA ISLAND GAS ORDER.

The inquiry by Mr. J. F. RONCA (Director of Gas Administration) into the application of the Portsea Island Gas Light Company for a Special Order under section 10 of the Gas Regulation Act, was resumed at the offices of the Board of Trade last Friday. The main purpose of the Order is to enable the Company to acquire the undertaking of the Havant Gas Company, and to extend the limits of supply. The previous proceedings were reported in the "JOURNAL" for Oct. 21, p. 175.

Mr. ROWAND HARKER (for the Portsea Island Company) announced that, as the result of discussions since the last hearing, the Company and the Portsmouth Corporation had reached an agreement with regard to the additional capital powers which it was proposed to grant, though there had not been time to discuss the matter with the Portsmouth Trades Council and Labour Party (who, in addition to the Portsmouth Corporation, had raised objections to several matters dealt with in the Order). The result of the agreement was that the additional capital would be reduced from £200,000 to £125,000. Automatically, the additional borrowing powers would be reduced by £37,500; so that the total reduction amounted to £112,500.

Mr. SCHOFIELD (for the Portsmouth Trades Council and Labour Party), when asked what effect this would have upon his opposition, said his main objection to the consolidation and conversion of capital, and to the granting of additional capital powers, was on the ground, not so much that the amount of interest which would have to be paid would be increased, but that, in the event of the undertaking being transferred to a public authority in the future, the tendency would be for the purchase price to be increased to the higher capital value rather than to be reduced to the real value.

Mr. HARKER, after pointing out that the questions of the additional capital and the conversion of existing capital were two separate points, said that, even assuming that in the future the undertaking would be acquired by a public authority, the purchase price would be based upon the income-earning capacity, and therefore it seemed to him that the question of the amount of additional capital authorized could not affect the question. If the purchase were based on the income-earning capacity of the undertaking, the larger the amount of capital expended, and which was not giving a proper return, the worse it would be for the vendors, and the better it would be for the public authority who were buying the undertaking.

Mr. F. J. WROTTESLEY (for the Portsmouth Corporation) said the Borough Treasurer had studied the accounts, and was satisfied that the conversion scheme would not expand the dividend-paying capacity. It was on that ground that the Corporation were able to approve of the proposals.

Mr. *William Cash* was then re-called to give further evidence as to the conversion scheme, and dealt with the suggestion made by the Portsmouth Trades Council and Labour Party that by it the Company were inflating the capital, which might be to the disadvantage of a public authority purchasing the undertaking in the future. He could not see how the scheme could have this effect, if it were agreed—as the Company had endeavoured to prove—that the scheme made no difference to the earning capacity or the capacity to pay dividends in the future.

Mr. SCHOFIELD, cross-examining, referred to the power in the Order to create a special purposes fund, and pointed to the provision whereby the money in that fund could be invested in securities in which trustees were authorized by law to invest, or might be applied for "the general purposes of the Company to which capital was properly applicable." He asked whether it was sound financial policy for a commercial undertaking to be allowed to invest money from such a fund in their own business.

Witness replied that it was. It was analogous to the power which was given to municipal authorities, which relieved them from the obligation to borrow money at a high rate of interest, by giving them authority to use their own sinking funds. He would be sorry to see the clause altered, because it had been discussed over and over again, and was absolutely in the model form. He also pointed out that this fund took the place of the old insurance fund, and it had to be maintained at a reasonable figure, because it was to be used for insurance purposes.

Mr. SCHOFIELD asked that the clause should be amended to ensure that the money in the fund should be invested in securities; and that when the money in this fund was used for capital purposes, that money should be a loan from the fund, and repayable to the fund.

Mr. RONCA suggested that Mr. Schofield's point might be met if it were stated that the money might be invested in securities in which trustees were authorized by law to invest, "or may be applied as a loan."

Witness replied that it would not make the slightest difference to the actual working of the fund. The object of the clause in its present form was to relieve the Company from the necessity of raising money in the market when money was dear, in order to invest the fund in Government securities.

The BOROUGH TREASURER suggested amending the clause so that the Company might "temporarily apply" the money to capital purposes.

Witness said he did not mind agreeing to the suggestion if it would help, but in his view the effect would be *nil*.

Mr. HARKER said that one had a natural reluctance to alter the form of a model clause, which had been inserted over and over again, not only by Parliament, but by the Board of Trade.

Mr. SCHOFIELD said that the Portsmouth Trades Council and Labour Party also opposed the consolidation clauses from the point of view that they were in the interests of the shareholders, and not of the consumers. He submitted that conversion was another form of writing-up the capital.

Witness replied that that objection was founded on misapprehension. All that was to be done was to exchange existing stocks for others with exactly similar rights; and the consumer was not hurt in the slightest. With all respect, he really considered that Mr. Schofield need not be concerned with regard to conversion on the ground that it would add to the transfer value of the undertaking.

Mr. SCHOFIELD then contended that a case had not been made out in respect of the additional capital powers asked for; and, although the figure had been reduced by agreement with the Corporation, he asked Mr. Cash if he still thought that the probable expansion of trade would justify the heavy increase.

Witness replied that at the present moment, in spite of the competition of electricity, gas companies were growing at a tremendous pace.

Reference was then made to a clause in the Order giving the Company power to offer additional capital by subscription, this power to be exercised only with the permission of the Board of Trade, and subject to such conditions as the Board imposed.

Witness said he had had experience of companies operating such a clause. The Croydon Gas Company, of which he was Chairman, had this power under their Act of 1922, and had used it twice with very good effect. He produced a circular which was distributed in March, 1925, by the Croydon Gas Company, offering to consumers and employees £79,000 of sliding-scale stock at £5 3s. for each £5. The whole amount was subscribed within a month or five weeks, without issuing any prospectus, and without paying commission to anybody. Another offer was made in the same way in September, 1925, when the Company offered £100,000 of 5 p.ct. maximum dividend stock at £4 5s. for each £5. About a fortnight ago £65,000 had been subscribed, without expense, except a little advertising in the local papers. He believed it had cost the Company about £300 to raise the first amount, and this included the printing of the circulars.

Mr. WROTTESLEY asked if, provided the clause were allowed, there would be any objection to inserting a provision that, before application were made to the Board of Trade for permission to offer stock in this way, notice in writing should be given to the Town Clerk of Portsmouth, who should be entitled to put forward objections to the Board of Trade.

Witness objected because it meant delay.

Mr. WROTTESLEY said that since 1877 it had been the practice of Parliament almost invariably to provide that gas capital should be raised under the provisions of the auction clauses.

Witness said there had been occasions when it had been extremely difficult to raise money under the auction clauses. If, by accident, the minimum price were fixed too high, there might be failure. He mentioned a recent case in which a company had failed, with most unfortunate results. They had offered the capital by auction the second time, and it meant that they had to go through a long procedure. Also, the people who bought part of it at the time of the first offer were very annoyed, because the remainder was sold ultimately at a lower price. The greatest objection to the auction clauses

was that, if there was a large issue coming, it was very difficult to get underwriters to take an interest in a sale by auction. The power which the Portsea Island Company now asked for, he believed, was first given in the South Metropolitan Company's Act.

Mr. WROTTESLEY pointed out that the Company were asking for something other than what was provided by the Standing Orders of Parliament, which stated that in every Bill by which an existing gas or water company were authorized to raise additional capital, provision should be made for the offer of such capital by public auction or tender at the best price at which it could be obtained.

Witness said it was convenient to have the power asked for. He considered it quite unnecessary for the Corporation to have power to go to the Board of Trade.

Mr. WROTTESLEY, addressing Mr. Ronca on this point, said it seemed a little unfortunate that the Company should have taken up the attitude they had. They were asking the Board of Trade to depart from the well-recognized code laid down by Parliament in 1877, and which had operated from that time. Was it unreasonable that, if the Company sought power to raise capital by subscription, the Corporation, who represented the consumers, should be allowed to go to the Board of Trade and make representations? There was not a shadow of a case even for suggesting the departure from the ordinary practice of Parliament.

Mr. HARKER said it seemed to have been overlooked by the Corporation that the power sought could not operate except with the consent of the Board of Trade, and subject to such conditions as the Board might impose. As to the suggestion that it was unfortunate that the Company should have taken up their present attitude, he emphasized the evidence of Mr. Cash as to the advantages resulting from the raising of capital by subscription. Commenting on Mr. Wrottesley's remark that the 1877 code had not been departed from, he asked whether gas legislation was to stand still. Could it not fairly be said that, in view of Mr. Cash's evidence as to experience at Croydon, the action of Parliament in 1922, when granting the power to Croydon, was amply justified, and had been to the benefit of all?

Mr. HARKER, dealing with the question of the repeal of various sections of the Company's Acts, said that one section in the Act of 1821 related to the power to alter the position of pipes. As this matter, together with the question of who should bear the expense of the alteration, was now under discussion by representatives of public utility companies and road authorities, and was also to be discussed in Parliament in connection with the Northampton Gas Order (see the "JOURNAL" for August 5, p. 341), the proposal to repeal the relevant section of the Company's 1821 Act was withdrawn, leaving it open to the Company, when the opportunity arose, to make the point again, either before the Board of Trade or before Parliament. With regard to a stand-by clause, which Mr. Harker said was to be dealt with later,

Mr. RONCA intimated that the Board of Trade considered it desirable that this should be much the same as the stand-by clause in the Electricity Acts. [This provides that persons taking a supply of electricity for stand-by purposes only shall pay a minimum sum.] He added that this was not a definite decision, but was an attitude of mind which it was as well to mention.

Mr. HARKER then referred to other sections of the Company's Acts which it was desired, by the Order, to repeal. These included sections of the 1821 Act, relating to the making of drains and the laying of pipes, which contained the provision that public streets should only be broken-up for those purposes with the consent of the Highway Commissioners (now the Portsmouth Corporation). The Corporation objected, however, to the cancellation of their rights. The Company were now under an obligation to supply gas to any premises within 25 yards of a main if a supply were demanded; but, though there might be a main within 25 yards of premises to which a supply was demanded, under the Company's existing legislation, it would be possible for the Portsmouth Corporation to exercise their right of veto and to prevent the breaking-up of the street for the purpose of laying a service pipe, thus depriving a would-be consumer of his supply. He knew of no other gas company subject to such a restriction, and the Portsea Company were taking the present opportunity of bringing their legislation up-to-date. It would also be possible, under the existing provision, for the Corporation to prevent the breaking-up of a street for the purpose of repairing a main. He did not suggest that in the past the Corporation had in any way hampered the Company in the carrying-out of their statutory duties. Another section of the 1821 Act which it was asked should be repealed related to the laying of pipes for ancillary purposes. This also provided that the consent of the Corporation must be obtained before streets were broken-up for that purpose. It was proposed to substitute for it a clause in the present Order which gave power to lay pipes for these purposes, and applied the provisions of the Gas-Works (Clauses) Act, 1847, excluding the necessity for obtaining the consent of the Corporation to break-up streets. The suggested clause was in a form in which it was frequently inserted in Acts and Orders.

Mr. *T. H. F. Lapthorn* (Chairman of the Company), in evidence, said that the Havant Company were not subject to the same restriction as the Portsea Company. With regard to the power to lay pipes for ancillary purposes, he said that the provision in the 1821 Act was very limited, and he had been advised by the Company's Engineer that an extension of it was needed, in order to meet present-day requirements. While he had had no difficulty in the past with the Corporation, the existence of the power of veto would be a temptation to some people to use it.

Mr. RONCA pointed out that it was the usual practice of the Board of Trade to add, to clauses such as it was now proposed to apply relating to pipes for ancillary purposes, a proviso that no main, pipe, or culvert should be laid down in any street without the consent in writing of the road authority, such consent not to be unreasonably withheld, and any differences arising to be determined by arbitration.

Mr. HARKER did not think the Company would raise objection.

Mr. WROTTESLEY, after cross-examining Mr. Lapthorn with a view to emphasizing the advances made in methods of road construction, and the increased importance of highways, said the sections it was proposed to repeal had operated for 104 years; and he submitted that the Board of Trade would not make alterations in codes set up by Parliament, unless there were established a *prima facie* case for the necessity of doing so. He suggested that no case had been made to show that the existing power affected the proper and efficient carrying-on of the undertaking, and that therefore the Board of Trade had not jurisdiction to make the alteration. There was never a time when highways were found to become so rapidly inadequate as now; and this was the wrong moment at which to start whittling-down the powers of those responsible for the maintenance and repair of highways. The Corporation attached the utmost importance to the provision. In Portsmouth there were peculiar conditions—there were narrow streets, the town was on an island, the drainage problem was by no means an easy one, and there was an extraordinary increase of traffic. The Company need not fear that, if the Corporation allowed a gas main to be laid within 25 yards of any premises, they would be likely to disallow the laying of a service pipe to the premises. It was an extraordinary thing how the proposed clause relating to the laying of pipes for ancillary purposes ever got into the Model Clauses of Parliament, because its effect was likely to be very serious indeed. Another clause, to the repeal of which the Corporation objected, was contained in the Company's Act of 1861, relating to meters for public lamps, the reason for the objection being that the clause placed a limit upon the price of gas for public lighting.

Mr. HARKER said he should have thought that the Corporation would be content with the protection afforded by the General Acts.

Mr. WROTTESLEY replied that the Corporation saw no reason why the privilege given them in 1861 should now be taken away.

Agreement was come to on a number of other matters raised by the Corporation.

Outstanding objections by the Portsmouth Trades Council and Labour Party were then considered. One of them related to a provision giving the Directors of the Company power to subscribe to any fund raised in case of national emergency, or in connection with the gas industry, to infirmaries, hospitals, and convalescent homes, and to the benevolent, sick, and welfare funds of the employees of the Company. It was urged that the term "national emergency" should be more clearly defined. Among other points was an objection to sanctioning borrowing powers up to one-half the issued capital, instead of one-third.

MIDLAND COAL PRODUCTS, LTD

Addressing the shareholders at the sixth annual general meeting on Oct. 29, the Chairman (Captain H. FitzHerbert Wright) said that during the year ended June 30 some part of the Company's carbonization plant was operated continuously, with the exception of six weeks' cessation during August and September, to allow the Nottingham Colwick Estates Power Department to consolidate the foundations of their 750 H.P. "National" gas engine. Gas of constant quantity and quality was maintained, demonstrating that, where suitable markets for the gas can be provided, there are undoubtedly possibilities for the commercial application of the Company's process and plant. The demand during the winter period, for the larger size of carbonized briquettes, was ten times that of the output, which is very significant, in view of the low price and demand which prevailed for other carbonaceous material. The smaller size did not, however, find such a ready sale. The distilled oil has always found a ready market, and the pitch has been used for briquetting purposes. A test of the Company's plant was conducted by H.M. Fuel Research Board from Jan. 20 to 23. The test was made without interruption; and the results are, on the whole, better than those claimed, showing a thermal efficiency of 94·5 p.ct., which is higher than that of any other carbonization plant. Arrangements have been made with the Nottingham Colwick Estates Power Department to supply additional gas. Important experimental work is in progress in order to produce a larger yield of fuel and oil and a gas of a high calorific value.

The balance-sheet showed that £67,750 has been spent on the development of the Company's process, which has now been brought to a stage at which the Directors look forward with some confidence to successful developments.

The report stated that the Company traded intermittently during the year; the loss thereon being £12,470. Every endeavour is now being made to push the manufacture and sale of the Company's products

TRADE NOTES.

Cannon Gas Fires.

Cannon Iron Foundries, Ltd., of Bilston, have published a new gas fire list and also a folder illustrating various types of heating apparatus. In appearance, efficiency, and detail finish "Cannon" fires bear the stamp of high-grade design and manufacture. Of particular interest in the new list is the series of inclined fires, which has met with pronounced success.

Agencies for India and Burma.

Mr. Burnup, of Messrs. Incell & Silk, Ltd., Calcutta, arrives in London on the 17th inst.; and is desirous of arranging agencies for sanitary, plumbing, and general engineering goods for India and Burma. Reference can be made to the Hong Kong and Shanghai Banking Corporation and the Imperial Bank of India, and interviews arranged at the office of the London Agents, Messrs. S. C. Clark & Co., Ltd., Broad Street House, E.C. 2.

CONTRACTS OPEN.

Acid Storage Tank.

The Tipton Urban District Council are inviting tenders for the supply and erection of a timber lead-lined acid storage tank. [See advert. on p. 305.]

NORTH-EAST COAST COAL TRADE.

From our Own Correspondent.

The market continues satisfactorily steady in all departments, and the inquiry is sufficient to point to a good demand for some time ahead. Many producers are now in quite a strong position for this month, and quotations are maintained at recent levels. On the other hand, pits which have been idle have been gradually coming into production, and, as this process is likely to continue, the probability is that prices will not rise for some time above the present attractive level.

The financial position in France naturally operates against business in that quarter; but the renewal to some extent of the export trade to Germany, and the better feeling in the industries at home, give confidence to the market. The latter factor has especially influenced the coke market, which is perhaps the most active section of all. Gas cokes ask from 22s. to 24s. f.o.b., and patent foundry makes are about 22s. 6d.

The Durham markets remain quite steady. Gas coals have been in good demand, 16s. 6d. to 16s. 9d. being quoted for Wear Specials, and 16s. 3d. to 16s. 6d. for best qualities. Seconds are good at 14s. 6d. to 14s. 9d., which is a considerable improvement on the price of a few weeks ago. Coking unscreened is in fair demand at 14s. 6d. to 14s. 9d., while unscreened bunkers are in request at about 15s. 6d. for best makes.

YORKSHIRE AND LANCASHIRE COAL TRADE.

From our Local Correspondent.

Collieries generally report that their markets are easier this week, the demand for large coals, both for inland consumption and export, having declined a little, probably owing to the mildness of the weather. At all events, pits on the average are working four days a week, although in many instances full time is in operation. In one or two restricted areas, there appears to be a more optimistic tone among industrial consumers, although it is so slight that no apparent effect has yet been felt.

The demand for washed coals for export continues to keep these fuels firm; but the situation is one that does not inspire marked confidence for any lengthy period ahead.

Gas coals are in better request, and for one or two "spot" orders recently on the market the prices have varied considerably, but for prompt business some low figures are quoted.

Humber bunker and export prices (f.o.b. usual shipping ports) are as follow: South Yorkshire—Hards, Association, 18s. 1½d. to 18s. 4½d.; screened gas coal, 17s. 6d.; washed trebles, 19s. 6d. to 21s.; washed doubles, 18s. 3d. to 18s. 6d.; washed singles, 17s. to 18s.; washed smalls, 13s. 3d.; unwashed doubles, 15s. 9d. to 16s. 3d.; rough slack, 9s. to 9s. 6d.; smithy peas, 18s. to 20s. per ton. West Yorkshire—Hartleys, 16s. to 18s.; screened gas coal, 16s. 6d.; washed singles, 16s. to 16s. 6d.; washed smalls, 13s.; unwashed trebles, 17s.; unwashed doubles, 13s. to 13s. 9d.; rough slacks, 9s. 6d.; coking smalls, 9s. to 9s. 6d. per ton. Derbyshire and Nottinghamshire—Top hards, 19s. 6d. to 21s.; washed singles, 16s. to 17s.; washed smalls, 13s.; unwashed doubles, 13s. to 15s.; rough slack, 9s. per ton. Yorkshire, Derbyshire, and Nottinghamshire—Screened steam coal, 15s. to 17s.; gas coke, 23s. to 26s.; furnace coke, 20s. 6d. to 22s. per ton.

New Carbonizing Plant for Leek.

The minutes of the Lighting Committee submitted at the last monthly meeting of the Leek Urban District Council contained a recommendation (which was adopted) that application should be made to the Ministry of Health for sanction to the borrowing of £13,530 for extending the plant at the gas-works. This minute arose out of a report of the Gas Engineer (Mr. R. H. Ginman) favouring the erection of a bench of eight Glover-West vertical retorts, with provision for an ultimate sixteen of these retorts, at an estimated cost of £6500. Mr. Ginman drew attention to the urgent need for replacing the obsolete and worn-out inclined retorts erected in 1900. Some mention was made by Mr. Shaw of the rapidly-growing indebtedness of the town; but Mr. W. A. Furmston (the Chairman of the Lighting Committee) pointed that provision was essential for the increase in the consumption of gas, which had been phenomenal, and was now three times the sales of 1900. The Committee could not jeopardize the supply to the town; and there was no doubt that the increase in the demand for gas in Leek was not a temporary one. They were unanimous that the work recommended by Mr. Ginman should be commenced at once. They might not want the whole of the £13,530 named.

Gas Company Co-Partners at Hove.—On Saturday, Oct. 24, at the Hove Town Hall, co-partners of the Brighton and Hove General Gas Company enjoyed a highly successful social evening. The company numbered well over 600. The esteem in which Mr. C. H. Rutter (the Engineer and General Manager of the Company) is held by the employees, and their appreciation of his efforts on their behalf socially, found tangible expression towards the close of the evening, when Mr. G. H. Mepham handed to him, amid heartiest applause, a Limoges coffee service (ornamented in silver gilt), half-a-dozen gilt spoons, and a silver cigarette box. Among the heads of departments present were Mr. H. V. Corfield, Assistant Engineer, Mr. P. E. Browne, Distributing Engineer, and Mr. C. A. Sandeman, Rental Superintendent.

USE Simmance's

DEAD BEAT INDICATORS

instead of WATER-TUBE GAUGES and

"READ THE PRESSURE BY THE POINTER."

No liquid to evaporate and no levels to adjust.

No glasses to break and nothing to clean.

Direct reading, Open scale, Any range (Pressure, Vacuum, or Combination).

Incorrodible, Accurate, for foul or purified gas.

MADE IN MANY RANGES WITH TABLETS LETTERED AS DESIRED.

SOLE LICENSEES

ALEXANDER WRIGHT & CO., LTD., WESTMINSTER.

Agents: Australia—FYVIE & STEWART, 360, Collins St., Melbourne; Canada—W. P. ROPER, 143, Beaver Hall Hill, Montreal.

STOCK MARKET REPORT.

FRENCH affairs were a disturbing factor on the Stock Exchange last week, and there was considerable liquidation of inter-Bourse securities. Critics of the restoration of the Gold Standard are not being universally supported, and claims are being made that it has already had a reviving effect on British trade. Whatever the reason, there are signs of improvement in some industries, and the prospect of more settled monetary conditions is undoubtedly assisting to this end.

Dealings commenced in the new Victoria and Australia scrips at ⅝ premium. Gilt-edged stocks were quiet; and there was very little life in the Foreign Market or in Home and Foreign rails. In the Industrial section, the trouble at the Dunlop Rubber Works led to heavy selling of the Company's shares; and the financial position of Crosse & Blackwell was greatly improved by the sale of the "Branson" factory, which, it is understood, is to be used by the purchasers for the manufacture of artificial silk.

The activity which prevailed in the Gas Market during the previous fortnight continued during the whole of the week. In no less than thirteen companies the quotations were raised, some on improvements in the previous two weeks. Brentford "A" and "B" stocks, Brighton "A," Tottenham "A," and Wandsworth "A," Wimbledon and Epsom stocks all benefited to the extent of 3 points. In only one of these stocks—that of the Brighton "A"—is the quotation equal to that of the corresponding week in the years 1923 and 1924, so it will be realized that there is still room for further profitable dealing. The Sheffield stocks were an exception to the general rule, all three stocks falling 2½ points. The quotations at the local exchanges are moved both upward and downward with more frequency than on the London Exchange.

The following transactions were recorded during the week:

On Monday, Alliance and Dublin 69, 69⅞, 70, 70⅛, Brentford "B" 96½, 5 p.ct. preference 95½, British 106, Continental Union 39½, 40, 40⅛, 41, 41⅛, 41⅜, 42, European 7, 7 7/32, Gas Light and Coke 82½, 83, 83⅛, 83½, 4 p.ct. preference 79, 80, 3 p.ct. debenture 60½, Imperial Continental 148⅜, Malta and Mediterranean 85s., Primitiva 12s. 10½d., 13s., 13s. 3d., South Metropolitan 91¼, 92, 92¼, 6½ p.ct. debenture 102, Tottenham "B" 88, 89. Supplementary prices, Aldershot new 4 p.ct. preference 73½.

On Tuesday, Brentford "A" 98, 4 p.ct. debenture 78½, Commercial 3 p.ct. debenture 57⅜, 58½, Continental Union 41½, European 6⅜, 7, Gas Light and Coke 82⅜, 83½, 83⅞, 84, 84½, 3½ p.ct. maximum 60, 4 p.ct. preference 70½, Imperial Continental 145, Montevideo 69½, Primitiva 12s. 0d., 13s., 13s. 1½d., 13s. 3d., 13s. 4½d., San Paulo 6 p.ct. preference 7⅞, South African 7, South Metropolitan 92, 92½, 3 p.ct. debenture 50½, Tottenham "B" 88, 89, 4 p.ct. debenture 76. Supplementary prices, North Middlesex 5 p.ct. preference 88.

On Wednesday, Commercial 4 p.ct. 80, Continental Union 40, 40¼, 40⅜, Gas Light and Coke 83⅜, 83½, 84⅛, 4 p.ct. preference 79, 3 p.ct. debenture 60, 61, Montevideo 69½, 70⅛, Primitiva 13s., 13s. 1¼d., San Paulo 6 p.ct. preference 8, South African 7⅛, South Metropolitan 92, 92½, 3 p.ct. debenture 50½, 6½ p.ct. debenture 103, South Suburban 5 p.ct. debenture 96¼, Swansea 7 p.ct. preference 101. 102, 6½ p.ct. debenture 102, 103, Tottenham "B" 89. Wandsworth (Epsom Stock) 114.

On Thursday, British 105¼, 106, Commercial 4 p.ct. 80, 3 p.ct. debenture 57⅞, Gas Light and Coke 83⅛, 83⅜, 84, 84½, 3½ p.ct. maximum 60. Primitiva 13s., South Metropolitan 92, 93, South Suburban 5 p.ct. debenture 96, Tottenham "A" 108, 108¼, "B" 87½, 88¼. Supplementary prices, Cambridge University and Town 5 p.ct. debenture 95⅞.

On Friday, Alliance and Dublin 70, Bombay 10s. *ex* div., Brentford "B" 102. 5 p.ct. preference 95½. 4 p.ct. debenture 77. British 105⅛, 106¼, Commercial 4 p.ct. 80, 81. 81¼, Continental Union 40, Gas Light and Coke 84, 84⅛, 84¼, 85, 2¾ p.ct. maximum 61, 3 p.ct. debenture 61, Imperial Continental 145, 146⅜, Primitiva 12s. 9d., 12s. 10½d., 13s. 1½d., 13s. 3d., San Paulo 6 p.ct. preference 7⅞, 7 15/16, 5 p.ct. debentures 43½, 44. South Metropolitan 92½, 3 p.ct. debenture 58⅜, South Suburban 5 p.ct. 97, Wandsworth (Epsom Stock) 113. Supplementary prices, Wolverhampton 8 p.ct. debentures 105.

In Lombard Street there was no sign of the ease usually experienced in the Money Market at the end of the week, and it is expected that the tightness may be maintained until the release of the Government dividends on Dec. 1. Borrowers had to pay 3¼ to 3⅜ p.ct. for renewing day-to-day loans. The Treasury Bill average rate rose again by 1s. 4d. p.ct. to £3 16s. 1·72d., which is the highest for seven weeks.

The fall of the French Ministry had an immediate effect on the franc, and the rate actually touched 121¼ on Monday of last week—a new high record. The depression, however, was relieved by strong support being forthcoming, and on Friday it had improved to 115.45. On the other hand, the New York exchange firmed up, though there was a downward tendency at the end of the week, the closing quotation being 4.84 9/16. Belgian francs were steady at 106.85, and Italian lire were higher at 122⅜.

Gold was cheaper at 84s. 10½d. per oz., and Silver declined to 32 15/16d. per oz.

The Bank Rate is 4 p.ct., to which it was reduced from 4½ p.ct. on Oct. 1. Bankers' deposit rates are 2 p.ct. The deposit rates of the discount houses are 2 p.ct. at call and 2¼ p.ct. at notice.

Issue.	Share.	When ex-Dividend.	Dividends. Prev. Hf.Yr.	Dividends. Last Hf. Yr.	NAME.	Quotations. Oct. 30.	Rise + or Fall − on Week.	Transactions Lowest and Highest Prices.
£			%p.a.	%p.a.				
171,978	Stk.	Aug. 13	5	5	Aldershot 5 p.c. max. C.	75—78	..	..
395,492	,,	,,	4	4	Do. 4 p.c. Pref.	70—75	..	..
1,351,868	,,	Oct. 8	6½	6½	Alliance & Dublin Ord.	68—72	..	69—70½
374,000	,,	July 9	4	4	Do. 4 p.c. Deb.	60—65	..	..
300,000	1	Oct. 22	1/7½	1/7½	Bombay, Ltd.	¾—1*	..	19/-
170,000	10	Aug. 13	8½	8½	Bournemouth 5 p.c.	12—13	..	..
425,050	10	,,	7	7	Do. B 7 p.c..	12—12½	..	..
150,000	10	,,	6	6	Do. Pref. 6 p.c..	11—12	..	..
50,000	Stk.	June 25	3	3	Do. 3 p.c. Deb..	56—59	..	..
162,025	,,	,,	4	4	Do. 4 p.c. Deb..	77—80	..	..
992,045	,,	July 9	6 3/10	6 3/10	Brentford A Con.	98—103	+3	98
990,500	,,	,,	6½	6½	Do. B New	98—103	+3	96½—102
76,000	,,	,,	5	5	Do. 5 p.c. Pref.	95—98	+1	95½
306,690	,,	June 11	4	4	Do. 4 p.c. Deb.	76—81	..	77—78½
181,337	,,	,,	6	6	Do. 6 p.c. Rich. Red. Deb.	100—105	..	..
214,740	,,	Aug. 27	12½	12	Brighton & Hove Orig.	168—173	+3	..
244,300	,,	,,	9½	9	Do. A Ord.	135—140	+	..
1,287,500	,,	July 23	5	5	Bristol 5 p.c. max.	89—91a	..	..
855,000	,,	Oct. 8	7	8	British Ord.	105—110	+2	105½—105½
100,000	,,	June 25	7	7	Do. 7 p.c. Pref..	120—125	..	..
120,000	,,	,,	4	4	Do. 4 p.c. Red. Deb.	71—76	..	..
100,000	10	May 21	6	8	Cape Town, Ltd.	6½—7½	..	..
100,000	10	Apl. 23	4½	4½	Do. 4½ p.c. Pref..	6—6½	..	..
150,000	Stk.	June 25	4½	4½	Do. 4½ p.c. Deb..	69—74	..	..
626,860	,,	July 23	6	6	Cardiff Con. Ord.	98—101	..	..
237,860	,,	June 25	7½	7½	Do. 7½ p.c. Red. Deb..	101—104	..	..
137,150	,,	Aug. 13	6½	5	Chester 5 p.c. Ord.	90—95b	..	..
1,313,280	,,	July 23	5/14/8	5½	Commercial 4 p.c. Cap.	79—84	+1	80—81½
360,000	,,	,,	5⅝	5/3/4	Do. 3½ p.c. Cap.	71—84	+1	..
475,000	,,	June 11	3	3	Do. 3 p.c. Deb.	56—59	..	57½—58½
100,000	,,	Oct. 8	—	4	Continental Union, Ltd.	40—43	+1	39½—42
200,000	,,	,,	7	7	Do. 7 p.c. Pref.	87—90	..	..
660,000	,,	Aug. 13	6½	6½	Croydon sliding scale	96—100	..	..
284,975	,,	,,	5	5	Do. max. div.	81—84	..	..
498,270	,,	Aug. 13	9	6	Derby Con.	107—109c	..	..
55,000	,,	June 25	4	4	Do. Deb.	74—76c	..	..
1,002,180	10	July 23	4	6	European, Ltd.	6⅞—7⅛	..	6⅞—7 7/32
16,460,070	Stk	Aug. 13	5½	5½	Gas Light & Coke 4 p.c. Ord.	83—85	+1½	82½—85
2,600,000	,,	,,	3½	3½	Do. 3½ p.c. max.	60—63	..	60—61
4,062,235	,,	,,	4	4	Do. 4 p.c. Con. Pref.	77—80	..	79—80
4,761,930	,,	June 11	3	3	Do. 3 p.c. Con. Deb.	58—61	..	60—61
130,000	,,	—	10	10	Do. 10 p.c. Bonds	..	..	..
42,000	,,	—	7½	7½	Do. 7½ p.c. Ilford Deb.	..	..	..
82,500	,,	Sept. 10	6½	6½	Hastings & St. L. 5 p.c. Conv.	90—95	..	..
258,740	,,	,,	5½	5½	Do. 3½ p.c. Conv.	71—76	..	..
70,000	10	Sept. 24	10	10	Hongkong & China, Ltd.	18½—19½	..	..
86,600	Stk.	Aug. 13	10	10	Hornsey 7 p.c.	132—137	..	..
1,976,000	,,	May 21	10	59	Imperial Continental Cap.	143—148	−4	145—148½
226,170	,,	Aug. 13	3½	3½	Do. 3½ p.c. Red. Deb.	70—72	..	..
235,242	,,	Aug. 13	6½	6½	Lea Bridge 5 p.c. Ord.	95—100	+1	..
2,127,340	,,	Aug. 13	5½	5½	Liverpool 5 p.c. Ord.	82½—83b	..	..
600,000	,,	Sept. 24	7	7	Do. 7 p.c. Red. Pref.	101½—103½b	..	..
165,736	,,	Aug. 27	8	9	Maidstone 5 p.c. Cap.	118—128	..	..
63,480	,,	June 25	3	3	Do. 3 p.c. Deb.	55—60	..	..
75,000	5	June 25	3	7	Malta & Mediterranean	4—4½	..	4½
541,920	Stk.	June 11	4	4	Montevideo, Ltd.	68—72	..	69½—70½
2,061,315	,,	Aug. 13	5	5	Newcastle & Gateshead Con.	70½—71½d	−½	..
300,929	,,	,,	4	4	Do. 4 p.c. Pref..	75½—76½d	..	..
529,705	,,	June 21	3½	3½	Do. 3½ p.c. Deb.	68—69d	..	..
15,000	,,	Aug. 27	12	11½	North Middlesex 10 p.c.	160—170	..	..
75,940	,,	,,	8⅝	8 9/16	Do. 7 p.c.	115—120	..	..
300,000	Stk.	May 7	9	7	Oriental, Ltd.	100—105	..	..
188,120	,,	June 25	7½	7½	Plym'th & Ston'house 5 p.c.	110—115	+2	..
60,000	50	Aug. 27	14	14	Portsea Island B	93—96	..	..
100,000	50	,,	13	13	Do. C	90—95	..	..
2,289,909	1	—	—	—	Primitiva Ord.	12/6—13/6	..	12/9—13/4½
302,600	100	June 2	4	4	Do. 4 p.c. Red. Deb..	78—80	..	..
600,000	Stk.	July 23	4	4	Do. 4 p.c. Red. Deb. 1911	64—66	−1	..
193,744	,,	June 25	4	4	Do. B. Aires 4 p.c. Rd. Db.	65—67	..	..
264,496	,,	,,	4	4	Do. R'r P'te 4 p.c. Rd. Db.	65—67	+1	..
150,000	10	Sept. 24	6	6	San Paulo 6 p.c. Pref.	7½—8	..	7⅝—8
125,000	50	July 1	5	5	Do. 5 p.c. Red. Deb.	42—45	..	43½—44
270,000	Stk.	Aug. 27	5½	5½	Sheffield A	98—100s	−2½	..
419,968	,,	,,	5½	5½	Do. B	98—100s	−2½	..
1,047,000	,,	,,	5½	5½	Do. C	98—100s	−2½	..
90,000	10	June 11	6	4	South African	7—9	..	7—7½
6,609,895	Stk.	Aug. 13	6½	5	South Met. Ord.	92—94	+1½	91½—93
1,895,445	,,	July 9	3	3	Do. 3 p.c. Deb.	57—60	..	58½—59½
734,000	,,	Sept. 10	6½	6½	Do. 6½ p.c. Red. Deb.	101½—103½	+½	102—103
91,500	,,	Aug. 13	8½	8½	South Shields Con.	131—133d	..	..
1,187,795	,,	July 23	6½	6½	South Suburban Ord. 5 p.c.	96—100	+1½	97
368,837	,,	June 25	5	5	Do. 5 p.c. Deb.	95—98	..	96—96½
647,740	,,	Oct. 22	5	5	South'mpt'n Ord. 5 p.c. max.	78—81*	..	..
121,275	,,	June 25	4	4	Do. 4 p.c. Deb.	70—75	..	..
250,000	,,	Aug. 27	7	7	Swansea 7 p.c. Red. Pref.	100—102	..	101—102
200,000	,,	June 25	6½	6½	Do. 6½ p.c. Red. Deb.	101—103	..	102—103
120,000	,,	July 23	8	7½	Tottenham District A 5 p.c.	108—113	+3	108—10⁹⁄₁₆
882,275	,,	,,	6½	3½	Do. B 3½ p.c.	87—92	+2	87½—89
150,000	,,	July 9	—	28/4	Do. 5½ p.c. Pref.	103—105	..	..
181,455	,,	June 11	4	4	Do. 4 p.c. Deb.	76—79	..	76
258,251	,,	Aug. 27	5	5	Tynemouth Con. and New Uxbridge, Maidenhead, & Wycombe 5 p.c..	70—72d	+1	..
197,294	,,	Aug. 27	6½	6½	Do. 5 p.c. pref.	93—98	..	..
88,330	,,	,,	5	5	Do. 5 p.c. Maidenh'd	93—98	..	..
91,800	,,	,,	6½	6½	Wandsworth, Wimbledon, and Epsom—	88—93	..	..
50,000	,,	July 9	9½	8½	Wandsworth A 5 p.c.	128—133	+3	..
255,636	,,	,,	7½	7	Do. B 3½ p.c.	109—114	+2	..
392,955	,,	,,	6/9/6	5/19/0	Do. C and New	92—97	+2	..
255,000	,,	,,	7½	6½	Wimbledon 5 p.c.	103—108	+3	..
98,000	,,	,,	7½	7½	Epsom 5 p.c..	113—118	+3	113—114
88,416	,,	June 25	3	3	3 p.c. Deb.	56—59	..	..

Quotations at:—*a*,—Bristol. *b*,—Liverpool. *c*.—Nottingham. *d*.—Newcastle. *s*.—Sheffield. * Ex. div.

CURRENT SALES OF GAS PRODUCTS.

The London Market for Tar, Tar Products, and Sulphate.

LONDON, *Nov.* 2.

Business in tar products continues quiet, and there is little change in prices to record.

Pitch is steady at about 41s. 6d. to 42s. per ton f.o.b. works, and a moderate amount of business continues to be done.

Creosote is particularly firm, and something over 7d. per gallon net and naked at works is obtainable to-day.

Pure benzole and pure toluole are firm at 2s. 1d. to 2s. 2d. per gallon. Solvent naphtha, 95/160, is 1s. 10d. per gallon, heavy naphtha, 90/190, 1s. 5d. per gallon.

Phenol is quoted at 4¾d. per lb., but is weak.

Pyridine bases are about 18s. 6d. to 19s. per gallon filled into buyers' drums.

Tar Products in the Provinces.

Nov. 2

The markets for tar products have remained about the same during the past week.

In pitch, some sales have been reported on the basis of to-day's quotations.

Creosote remains firm.

Benzole and solvents are steady.

Cresylic acid shows signs of improvement.

The average values for gas-works products during last week were: Gas-works coal-tar, 27s. 9d. to 32s. 9d. Pitch, East Coast, 40s. to 41s. f.o.b. West Coast—Manchester, 34s. 6d. to 35s. 6d.; Liverpool, 35s. 6d. to 36s. 6d. Clyde, 37s. to 39s. Benzole, 90 p.ct., North, 1s. 7¼d. to 1s. 8½d.; crude, 65 p.ct., at 120° C., 1s. to 1s. 1d., naked at makers' works; 50-90 p.ct., naked, North, 1s. 7½d. to 1s. 8¼d. Toluole, naked, North, 1s. 6½d. to 1s. 7½d., nominal. Coal-tar crude naphtha, in bulk, North, 7½d. to 8¼d. Solvent naphtha, naked, North, 1s. 4½d. to 1s. 6d. Heavy naphtha, North, 1s. to 1s. 2d. Creosote, in bulk, North, liquid, 5⅝d. to 6d.; salty, 5⅜d. to 6d.; Scotland, 5⅝d. to 5¾d. Heavy oils, in bulk, North, 6¼d. to 6½d. Carbolic acid, 1s. 4d. to 1s. 5d. prompt. Naphthalene, £11 to £14; salts, £4 to £5, bags included. Anthracene, "A" quality, 2½d. per minimum 40 p.ct., purely nominal; "B" quality, unsaleable.

Manchester District Tar Prices.

The average price realized for the sale of tar in the Manchester district, according to the sliding-scale, for the month of September was £2 7s. 7·18d.

Meters Limited.—The Directors regret that the meter trade continues to be unprofitable, owing to the unsatisfactory prices obtainable; but they have decided to pay out of the reserves dividends for the half-year ended Sept. 30 at the rates per annum of 5¼ p.ct. on the preference shares and 4 p.ct. on the ordinary shares.

Reduced Price at Llandudno.—At a meeting of the Llandudno Urban Council last week, a recommendation of the Gas Committee that the price of gas be reduced was agreed to. The new prices, to take effect from the September quarter readings, are: Ordinary consumers, 4s. 10d. per 1000 c.ft., less 5 p.ct. discount; and slot meter consumers, 4s. 11d. per 1000 c.ft. It was also decided to apply to the Ministry of Health for sanction to borrow £8131 for gas-works extension purposes. This sum is made up of money spent during the past two years, together with estimated expenditure in the coming three years.

Gosport District Gas Company.—Messrs. A. & W. Richards have been instructed to offer for sale by tender £25,102 of new capital, in the form of redeemable mortgage bonds, irredeemable preference stock, and consolidated ordinary stock, in the Gosport District Gas Company. An announcement regarding the offer will be found in our advertisement pages. Tenders must be sent to the firm, at No. 37, Walbrook, London, E.C. 4, by 11 o'clock on Thursday, Nov. 12. In view of the substantial reduction which has been made in the price of gas in the Fareham area as a result of the amalgamation of the Fareham and Gosport Companies, a considerable increase in the sales of gas in this part of the district is taking place. The Company's works at Gosport have been largely reconstructed and brought up-to-date by the introduction of modern machinery and plant, and are now in a position to meet all the anticipated requirements of both the Gosport and Fareham districts. It is to meet the cost of these extensions, and to enable the Company to continue to provide for their extended business, that the capital now being offered is required.

St. Dunstan's.—The best evidence of the faith of the public in the necessity for the continuance of the work St. Dunstan's is doing, and of the sustained sympathy which is universally felt for the objects for which the organization exists, is provided in the fact that the balance-sheet accompanying the tenth annual report shows a reasonable excess of income over expenditure. Although this sound financial position is largely due to the incidence, in the period covered by this report, of a very generous legacy, yet it is fine tribute to the businesslike administration of such a vast organization that, nearly seven years since the war finished, St. Dunstan's is able to find support from all quarters of the Empire for the carrying out of the task to which it set its hand a full decade since. The pages of the report summarize the remarkably varied character of the work undertaken by St. Dunstan's in the training, settlement, and life-long aftercare of men blinded by war service. Almost everyone is familiar with the methods which have been employed to secure so striking a measure of success; but it should be emphasized that, as the organization depends entirely upon voluntary support, any future decrease in this must jeopardize the efficiency of the services it can render.

APPLICATIONS FOR PATENTS.

[Extracted from the "Official Journal" for Oct. 28.]

Nos. 26,022-26,718.

CARLTON MAIN COLLIERY COMPANY, LTD.—"Retorts, &c., for low-temperature carbonization of coal." No. 26,383.

CARLTON MAIN COLLIERY COMPANY, LTD.—"Low-temperature carbonization of coal, &c." No. 26,605.

DU BE, R. E.—"Gas engines." No. 26,209.

ELDRIDGE, H.—"Ventilation of rooms containing gas fires." No. 26,454.

GIBBONS BROS., LTD.—"Retort settings." No. 26,291.

HUETTIG, A. R.—"Gas meters." No. 26,370.

KROMSCHRODER AKT.-GES., G.—"Dry gas meters." No. 26,466.

LODGE-COTTRELL, LTD.—"Fractionation of Distillation Products." No. 26,251.

LORAM, E. R.—"Gas meters." No. 26,705.

LURGI APPARATEBAU-GES.—See Lodge-Cottrell, Ltd. No. 26,251.

MASCHINENFABRIK AUGSBURG-NÜRNBERG AKT.-GES.—"Waterless gasholders." No. 26,103.

MASTERS, E.—See Gibbons Bros., Ltd. No. 26,291.

METALLBANK UND METALLURGISCHE GES. AKT.-GES.—"Apparatus for low-temperature distillation of fuel." No. 26,448.

POPE, P. C.—See Carlton Main Colliery Company, Ltd. Nos. 26,383, 26,605.

REESON, J. N.—"Application of tar to road metal, &c." No. 26,617.

WHITE, O.—"Apparatus for charging gas retorts." No. 26,411.

WUSSOW, R.—"Methods for dry cooling coke." No. 26,445.

Reduction in Price of Rawmarsh Gas.—The price of gas supplied by the Rawmarsh Urban District Council has been reduced 3d. per 1000 c.ft. in cases of slot meters and current accounts.

Punch's Almanack.—Our dear friend "Punch" has brought out his "Almanack" for 1926. In life, brightness, colour, and banter he has excelled himself; and offers it all for the modest shilling.

The Upholland Coking and Bye-Products Company, Ltd., has been registered as a private company, to enter into an agreement with Benzole and Bye-Products, Ltd. The nominal capital is £5000 in £1 shares.

New Horizontal Retorts at Dewsbury.—The new installation of horizontal retorts at the Dewsbury Corporation Gas-Works is now in successful operation. The work was only commenced last March; Messrs. Gibbons Bros. being the contractors.

Darlington Gas Department.—The accounts for the year ended March 31 show a net profit of £70, which has been allocated to gas-works reserve account. The total expenditure was £101,087, and the income £110,779. Sales of gas amounted to £78,844; and for residuals £26,939 was obtained.

Louth Gaslight Company.—It was reported by the Chairman (Mr. W. C. Street) at the annual meeting that the Company had almost doubled their output in the last ten years, and the price of gas has during the past year been at pre-war rate. The balance of profit and loss account amounted to £5767; and dividends were declared as follows: Original capital, 15¾ p.ct.; improvement stock "A" and "B," 5 p.ct.; and new ordinary stock at 12¾ p.ct. The carry-forward is £3980.

Staveley Company's Up-to-Date Coke Ovens.—The Staveley Coal and Iron Company have introduced at their Devonshire Works a battery of 70 of the latest type of coke ovens, which will take the place of 100 obsolete ones. Of these 70, 35 are already in operation; and when the whole number are working the output will be about 800 tons of coke a day, or nearly double the output of the old plant. The scheme for bringing the coke-oven plant up to date has been carried out under the direction of Mr. C. Whitehead, the Manager of the Devonshire Works.

The Ministry of Health have sanctioned the borrowing by Lytham St. Annes of £2550 for the acquisition of gas showrooms and offices at Lytham.

The literary section of the Great Harwood Wesleyan Church were addressed last week by Mr. A. J. Harrison (General Manager of the Accrington and District Gas Board) on "The Conservation of Coal."

Messrs. Alder & Mackay, Ltd., gas meter manufacturers, have appointed Mr. T. D. Hamilton, J.P., to be their representative over the whole of Ireland. His office will be at their Alfred Street Works, Belfast.

The Budleigh Salterton Urban District Council have expressed appreciation of the Gas Company's action in improving, on their own initiative and gratuitously, in various respects, the public lighting of the town.

The Directors of the Montevideo Gas and Dry Dock Company, Ltd., have declared an interim dividend on the ordinary stock of the Company for the half-year ended June 30 last of 2 p.ct. (actual), free of income-tax, payable on Dec. 1. This is the same as in the previous year.

The owners of the Clayton Hall Estate at Great Harwood and Clayton-le-Moors have sold their holdings. The Accrington Gas Board were the purchasers of the rent charge of £128 0s. 0d. arising from the plot of land on which the Great Harwood Gas-Works are situated; the price paid being £2370.

Replying in the Blackpool Town Council on Wednesday to remarks about delay in supplying gas to new houses, Mr. Newsome (Chairman of the Gas Committee) said they were doing their best to cope with the increased demand, and had connected 1000 new consumers this year. There was no delay where mains were already laid.

NEW EDITION.

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The article by a member of the staff of an Electricity Undertaking which appeared in the "JOURNAL" for July 1 last (pp. 31 and 32) has been reprinted in 8vo. size.

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COKE COMPETITION NUMBER.

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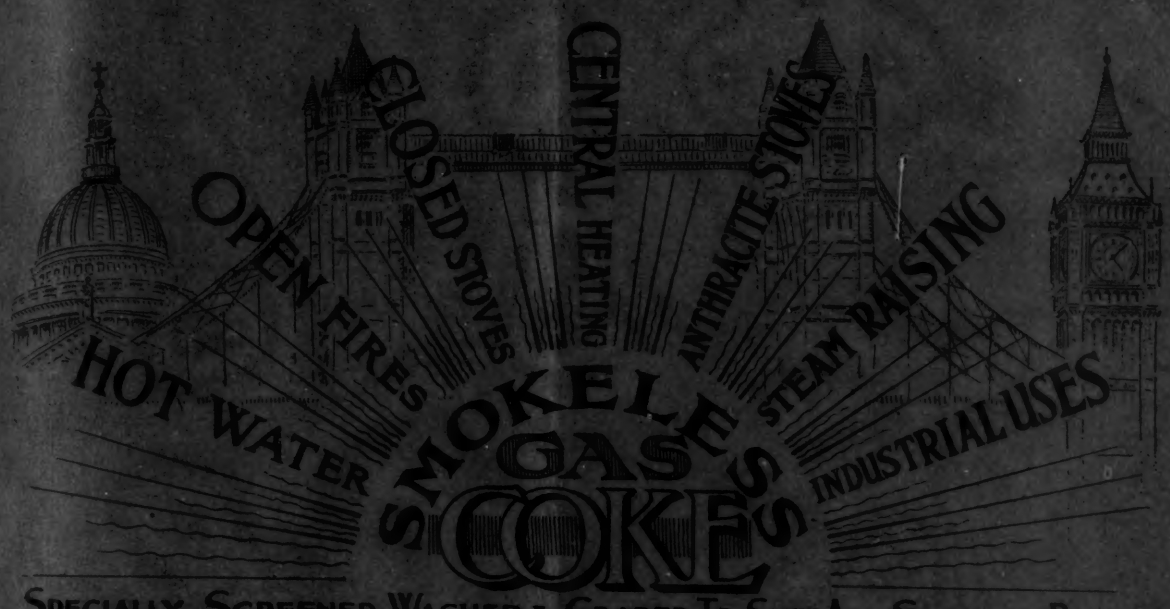

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GAS JOURNAL

WINNING PAPERS IN THE COKE COMPETITION.

[Only those to which awards above £10 were made are published in this number.]

FOREWORD.—The Coke Competition was originally suggested to the Editor of the "Gas Journal" by Sir Arthur Duckham, K.C.B. In his opinion, circumstances were such that it was necessary an attempt should be made to stimulate interest in, and a thorough study of, the questions of gas-coke production, handling, preparation for the market, utilization, and sales. The Woodall-Duckham Companies offered to provide £1000 for awards in such a competition if the Editor of the "Journal" would undertake to organize it, and providing that they could withdraw from all participation in the work, and merely occupy in relation to the competition the same independent position as any other unit of the gas industry. The Editor accepted the trust. Mr. A. W. Smith, the General Manager of the Birmingham Corporation Gas Department, Mr. W. B. Leech, the Engineer of the Beckton Works of the Gas Light and Coke Company, and Mr. Arthur F. Bezant, the Editor of the "Journal," were appointed the Adjudicating Committee. The competition was thrown open to anybody in the world competent to take part in it, within the conditions and rules laid down. These included the safeguarding provision (for contributors and Committee alike) that all papers submitted should only bear a *nom de plume*, and that the name and address of the writer or writers should be enclosed in a sealed envelope. The sealed envelopes were not opened until after the contributions had all been read separately by the Judges and the awards had been made. The awards and the report of the Committee were published in the "Journal" for Oct. 7.

A SHORT BIBLIOGRAPHY OF COKE.

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SECTION I.

COKE PRODUCTION.

First Award, won by "Lux ex Tenebris."

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A Study of the Principles and Practice of Coke Manufacture, with Particular Regard to Gas-Works Practice.

1. Introduction.

2. Economics of Coke Production as they Affect the Gas Engineer.
Statistics.
Relation of Coke and Gas Prices.

3. Applications of Industrial Coke and Qualities Required.
Domestic, Industrial, and Blast Furnace Coke.
Combustibility and Reactivity.
Suitable Grading.
Dryness.
Strength.
Low Ash Content.

4. Factors Affecting Coke Quality.
(*a*) Grinding and Size of Coal.
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Discussion on Pores and Cell Walls.

7. Laboratory Control of Blending.

1.—INTRODUCTION.

For all practical purposes coal is the sole source of generated heat, light, and power available in this country. Of the total coal mined, amounting to something under 270,000,000 tons per annum, 180,000,000 tons are used at home, and approximately 84,000,000 tons exported. Of the quantity consumed at home, all but about 40,000,000 tons are used in the raw state, this 40,000,000 tons being absorbed by gas-works, coke ovens, and producer gas plants. About another 40,000,000 tons are used for domestic purposes—namely, in the domestic grate.

In recent years, there has been an increasingly popular movement against the atmospheric pollution caused by the use of raw coal, and, as a result of very thorough investigation, it is now accepted that the domestic grate is the chief cause of atmospheric pollution. It is accepted that coal smoke, by masking the effect of the actinic solar rays, is detrimental to public health; and the attendant dirt, in its effect on public buildings, house decorations, and personal linen, is an unnecessary care and wasteful expense to the community as a whole. Consequently much has been done to encourage the use of gas and electricity—smokeless forms of heat, light, and power—in place of raw coal for domestic and industrial purposes, and a great deal of development has taken place in an attempt to produce a patent coke for domestic purposes by processes depending on the low-temperature carbonization of coal. Unfortunately there has been practically no co-ordination among those competing for substitutes for coal; and while gas is largely used for heating purposes, it has not taken the place of domestic coal to an extent sufficient materially to affect the smoke nuisance. Electricity for heating purposes is in a still worse plight. Not only is it a wasteful application of coal to produce electricity for heating purposes, but the cost of electricity is generally accepted as being too great for domestic heating. Gas is still too dear for domestic heating if gas alone is used. It is the most efficient way of utilizing coal, to heat by means of gas, but the average householder cannot bring himself to dispense completely with the use of solid fuel. This is a prejudice which is difficult to overcome, and, apart from this prejudice, the cost of gas heating is, in most cases, too high to tempt him from older methods. There is, therefore, a great field for the development of a satisfactory solid smokeless fuel, whether it be ultimately generally used for central heating or for the open fire, and whether alone or in conjunction with gas.

The aim of this paper is to show that, if the gas industry, using the present high-temperature methods of carbonization, will give as much attention to the production of coke as it does to the production of gas, sulphate of ammonia, benzole, &c., there is no doubt whatever that a really satisfactory free-burning solid smokeless fuel can be made without necessitating any reconstruction or substitution of already existing carbonizing plant.

The solid residue, known as coke, from the distillation of coal is a material worthy of as much study as any other product obtained from coal. Too long has it been considered merely as a bye-product. This is almost incomprehensible when it is realized that between 65 and 75 p.ct. of the weight of the coal used in gas-works remains as coke, and but 20 to 30 p.ct. of the weight of the coal appears as the so-called main product. In the coke oven industry similar short-sighted conditions have held. There, coke has been considered the main product, and the resultant gas has been used wastefully. These conditions are gradually changing, and more and more coke oven gas is being used for town purposes, and at the present time a considerable amount of attention is being given by experts to the improvement of the coke made in both these industries, with a view to making it satisfactory for domestic purposes.

Most of the coke made in the gas industry is used for industrial purposes. There are a few gas undertakings who make a speciality of screening and grading coke into sizes which will suit the various purposes to which coke is applied. Such progressive undertakings also realize the importance of buying coals which are not only suitable for gas-making purposes, but which will give a satisfactory coke when properly quenched.

The question is sometimes raised as to what would be the effect of producing all the domestic coke that would be required if it were to displace coal. At the present time there are approximately 6½ million tons of coke sold by gas undertakings, largely for industrial purposes, and 40 million tons of coal are used domestically. The change-over from coal to a satisfactory free-burning smokeless fuel could only take place gradually, though it would be much quicker than some

think if such a fuel were to be sold at a price comparable with domestic coal, and be at the same time satisfactory as a free-burning smokeless fuel.

There should be no alarm on this ground. At the present time, and for many years past, the coke market is, and has been, an extremely precarious one. The fluctuations from a good demand to slump conditions are well known, and are fully appreciated by the gas engineer. With every slump in trade there is a slump in coke.

In a normal modern house, where gas and coal are used with maximum convenience and efficiency, the quantity of solid fuel required by the house and the quantity of town gas required are proportionate to the relative quantities supplied from a ton of normal gas-making coal. In other words, for every half-ton of coke required for domestic purposes in any given average house, under the conditions stated above, the householder will use approximately 12,000 to 15,000 c.ft. of gas. By finding a regular and constant outlet for an improved coke, the value of the coke made should be considerably enhanced, and consequently the price of gas will be reduced, with a subsequent increase in its consumption; and there would appear to be no doubt that, by increasing the use of coke for domestic purposes, there would be a greater use of gas for domestic purposes. Apart from this, a reduction in the price of gas would immediately mean a very considerable increase in the use of gas for industrial purposes—this being the most acceptable form of heat for most processes, subject to the cost being sufficiently low. It is also quite conceivable that, if a first-class free-burning smokeless fuel could be produced on gas-works, it would be economically sound to use some of the gas for process work on the gas-works themselves. This stage, however, has not been reached, and it may never be necessary to adopt this suggestion.

This paper has for its aim the following objects. First, to summarize in one paper the principles of the production of coke, and, secondly, to indicate the possibilities available on all carbonizing plants for the production of a really satisfactory free-burning solid smokeless fuel to displace coal.

The subject of blending is treated in some detail. This is important from many points of view. The primary objective is to show that, by blending and correct subsequent treatment, a satisfactory solid smokeless fuel may be produced. A secondary objective is to show that cheaper coals, which are not now available to the gas industry, because of their low or non-existent caking quality, can, with great advantage, be used when blended in the production of an improved coke. This would immediately have the effect of reducing the prices of gas and coke, or enhancing the profits as the case may be. The same advantage would accrue from the utilization, by means of blending, of the coke dust, amounting to 10 p.ct. of the make of coke. This coke dust has a very low value as at present utilized, but it can be given a value equal to that of the best-grade improved coke.

The objection may be raised that such pre-treatment—namely, screening, blending, coal cleaning, &c.—would be prohibitively expensive. All that can be said here is that, so far as the subject has been examined, it has been found that the over-all costs of such treatment, in by far the majority of cases, are only a fraction of the financial advantages to be gained.

There has been no attempt in this paper to put forward novel suggestions and previously undisclosed processes. The future of solid smokeless fuel production depends on the gas industry, and the first requirement is the co-ordination of the known facts concerning coke. It is with this object in view that the present paper is presented.

2.—ECONOMICS OF COKE PRODUCTION AS THEY AFFECT THE GAS ENGINEER.

Coke Statistics.

During 1924 the total production of coke and coke breeze from gas-works in the United Kingdom amounted to 12,085,691 tons. Of this quantity, 7,419,305 tons were sold, the value at works being £10,854,517. The value of the separate items coke and coke breeze cannot be dissected completely, but, as nearly as can be ascertained, the average selling price for the coke was 29s., and for coke breeze 11s.

Gas-works coke represents only 48·6 p.ct. of the coke made during the year; the total production being 24,839,049 tons, of which quantity 12,753,358 tons were made in coke ovens.

The exports of gas-works and oven coke during 1922, 1923, and 1924 are given in Table 1.

TABLE 1.—*Export of Gas-Works Coke.*

Year	1922.	1923.	1924.
Tonnage	911,307	1,224,302	964,539
Value	£1,287,079	£1,990,532	£1,682,203
Value per ton	28s. 3d.	28s. 3d.	34s. 10d.
Average selling price of total coke sold	29s. 6d.	27s. 9d.	29s.

Export of Oven Coke.

Year	1922.	1923.	1924.
Tonnage	1,602,671	2,745,905	1,847,672
Value	£2,352,971	£6,383,140	£2,999,822
Value per ton	29s. 6d.	46s. 6d.	32s. 6d.

From this it is seen that, during 1924, the export price of gas-works coke (34s. 10d. per ton) exceeded the average selling price of the coke made (29s. per ton), while in 1922 the export price for gas coke was slightly less than the average selling price of coke.

Table 2 shows that, though the amount of coal carbonized on gas-works has increased during the past three years, yet the coke sold in this country per ton of coal carbonized has decreased.

TABLE 2.

Year	1922.	1923.	1924.
Coal carbonized, tons.	16,556,000	17,202,000	18,104,000
Coke made, tons	10,862,666	11,508,241	12,085,691
Cwt. per ton coal carbonized	13·11	13·38	13 35
Coke sold, tons	7,737,718	7,542,867	7,419,305
Cwt. per ton coal carbonized	8·9	8·78	8 2
Coke sold in U.K., tons	6,826,411	6,318,565	6,454,766
Cwt. per ton coal carbonized	8·24	7·35	7·13

Relation of Coke and Gas Prices.

The value and yield of coke is a factor of considerable importance in determining gas price. The published figures for the 1924 results for the leading gas companies show that, on the average, the coke sales represent 20 p.ct. of the total revenue.

	P.Ct.
Gas Light and Coke Company	20·2
South Metropolitan Gas Company	21·8
Birmingham Corporation	20·2
Manchester Corporation	19·0
Glasgow Corporation	16·3

The price realized for gas-works coke depends upon the laws of supply and demand. The gas engineer has to produce a given amount of gas, and, unless he is prepared to convert it into water gas, he produces a definite amount of coke. In districts where there is a good demand for industrial fuel a ready sale is usually found for suitably prepared coke, except in times of trade depression. The export market for coke is, of necessity, a fluctuating one, and a complete dependence for coke sales upon the export of coke would not ensure a satisfactory balance-sheet.

As has been pointed out in the introduction, the most certain and regular market is the sale of coke for domestic purposes; and it would seem that the production of coke in the form of a free-burning smokeless fuel on the gas-works would ensure a ready sale for all the coke made, and at the same time increase the financial return from coke.

In order to show the effect of coke price upon the cost of gas, the following calculations are made from the published figures of the South Metropolitan Gas Company for 1924. These figures are used as there are no complications in the statistics due to water gas production. The cost of production per therm sold is as follows:

	Pence.
Coal	4·986
Less: Coke	2·569
Breeze	·044
Tar	·453
Ammonia products	·284
	3·35
Net cost of coal	1·636
Cost of manufacture (salaries, carbonizing wages, purification, and repairs)	2·464
Cost into holder per therm sold	4·100

The yields and consumption of coke were as follows:

Coke made per ton of coal carbonized	12·26 cwt.
Coke breeze made per ton of coal carbonized	2·06 cwt.
	14·32 cwt.
Coke used per ton of coal carbonized.	2·43 cwt.
Coke breeze used per ton of coal carbonized	0·83 cwt.
	3·26 cwt.

The effect on the cost of gas into holder of an increase in the price realized for coke and of an increase in the amount of coke sold per ton of coal carbonized is shown in the following table, based on the above figures.

Coal at 28s. 5d. per Ton.

Coke Price.	Coke Sales 10·15 Cwt. per Ton.		Coke Sales 12 Cwt. per Ton.	
	Cost of Gas into Holder. Pence.	Percentage Saving in Cost of Gas.	Cost of Gas into Holder. Pence.	Percentage Saving in Cost of Gas.
s. d.				
29 2	4·100	..	3·634	11·35
30 0	4·027	1·78	3·544	13·55
31 0	3·939	3·93	3·444	16 00
33 0	3·761	8·26	3·234	21 10
35 0	3·584	12·60	3·024	24·55
37 0	3·409	16·80	2·814	31 30
40 0	3·144	23·50	2·502	38·90

As an example of the effect of coke price upon the financial balance-sheet, it is interesting to note that, during 1924, taking the published figures of the South Metropolitan Gas Company, an increase in the selling price of coke of 1s. per ton would have increased the profits by £30,000, or 8·3 p.ct. on the gross profits.

In the present paper, it is shown that, by the adoption of blending, coke breeze can be returned to the process, with the result that the whole of the coke sold receives a full market price. It is reasonable to assume that, if there was a ready sale of the whole of the output of gas-works coke for domestic purposes, as smokeless fuel, the average selling price would approximate to that of household fuel. With a large demand for his coke, the gas engineer would be likely to consider the advisability of selling as much of his make of coke as possible. In all probability he would find it economical to supply the heat for carbonization from external producer plants working on low-grade slack coals, and thus increase his coke sales to 13 cwt. per ton of coal carbonized.

Recent years have shown great advances in the yields of gas obtainable per ton of coal carbonized. Complete gasification, gas-making in vertical retorts under steaming conditions, and other processes of gas-making have all received careful consideration, and the limits of their effects on gas price have been studied. It is suggested that the most fruitful field for the future study of the ways and means of producing cheap gas is in the solid residue coke. The production of coke in the form of a free-burning smokeless fuel, coupled with the use of a wide selection of coals made possible by blending, would have a far-reaching influence on the economics of gas production.

3.—APPLICATIONS OF INDUSTRIAL COKE, AND QUALITIES REQUIRED.

The actual and possible applications of coke are many, but they can readily be grouped into three large classes:

(*a*) Industrial.
(*b*) Domestic.
(*c*) Metallurgical.

These, again, can be subdivided into smaller groups, each of which has generally one particular property of paramount importance. In Table 3 are set forth these groups, together with the chief qualities which coke, if it is to be considered a satisfactory fuel, must possess. In all cases low moisture, low ash, and good combustibility—that is, ease of combination with air—are considered essential. Moisture absorbs heat from the combustion of the coke, largely in a form useless for practical heating purposes. Ash is obnoxious, since it does not give out heat, and causes trouble and expense in its disposal. Good combustibility is essential, so that heat development will be rapid, and a live fire can be retained with a minimum of draught.

Consideration of the uses of coke in Table 3 leads to the conclusion that the only instance in which the utmost ease of ignition is of paramount importance is that of fuel for burning in open grates; and this, then, is the only case where there is any question of the suitability of a high-temperature coke as produced with the present conditions of manufacture.

A few notes as to the considerations which have governed the foregoing classification of cokes may be of interest. For all steam raising, small furnace, and domestic work (other than for open grates) the size is the main varying factor. This, generally, is conditioned either by the size of the stove or hearth, or whether natural or forced draught can be applied. For example, with the closed stoves and coke boilers of small capacity, for domestic houses and greenhouses, a small-sized screened coke is required. For the heating of institutions, &c., where the grates are larger, but hand stoking and natural draught only are available, a screened larger-sized coke is better. Electricity stations, and other raisers of steam in large quantities where mechanical stokers and forced draught can efficiently be applied, can burn almost any size of coke, particularly the small sizes.

With enclosed stoves and coke boilers of small capacity, the specific gravity is of some importance. A heavier coke allows of a greater weight of combustible matter being charged at once, and this is of advantage when banking for the night.

The fusibility of the ash is of very great importance where quick rates of combustion necessitating high air velocities are met—such, for instance, as in the "blow" period of water gas manufacture.

The strength of the coke is of greatest importance when considering the requirements of the blast furnace for foundry work and for exports. The small screened coke which can be used in other cases is generally strong enough to withstand the usual handling. In passing, it may be mentioned that the strength of coke may be considered from three aspects—namely, resistance to direct compression, resistance to shatter, and resistance to abrasion. Resistance to shatter is what is required when large coke has to withstand handling, and remain large coke. With the exception of blast furnace and foundry work, and for export, and some few special uses (such as in lime burning), the other demands for gas coke are in graded sizes. The type of strength these should possess is that of resistance to abrasion. Coke having large pores with thin walls, and irregular structure, is extremely liable to abrade; and this can be improved by adopting means as suggested in the following sections, which will give a regular structure with small-sized pores.

Specific gravity has been referred to so far in connection with the weight of material which can be placed in a given confined space. Beyond this, it is generally considered that a coke with a low specific gravity will have a high combustibility.

Low sulphur, though desirable in all uses, is essential for such as blast furnace and foundry work.

The qualities required in coke for industrial purposes may thus be said to comprise the following:

(1) Suitable grading.
(2) Suitable dryness.
(3) Low ash content.
(4) Low sulphur content.
(5) Satisfactory combustibility and reactivity.

TABLE 3.

Use of Coke.	Ash.	Size.	Specific Gravity.	Strength.	Burning Properties.	Other Properties.
(*a*) Heating of institutions, schools, public offices, &c.	Low in amount and medium to high fusibility	Medium large	Medium	Medium	Medium	..
(*b*) Stoves, central heating and hot water supplies for houses, greenhouses, &c.	Low in amount and medium to high fusibility	Screened, sizes between ½ in. and 2 in.	,,	,,	,,	..
(*c*) Small coke furnaces in industry	Low in amount and medium to high fusibility	Medium and large coke, screened	Medium to high	,,	,,	..
(*d*) Steam raising in electricity stations, laundries, and other industries requiring bulk supplies of steam	Low in amount and medium to high fusibility	Any size except large, depending on type of grate and draught	Medium	,,	Free	..
(*e*) Open grates	Low in amount. Fusibility not of prime importance	¾ in. to 1¼ in. and 1¼ in. to 2 in.	Low	,,	Free and easy of ignition	..
(*f*) Exports for purposes similar to (*a*), (*b*), (*c*), and (*d*)	Low in amount. Medium to high fusibility	Run of retort-house coke without fines	Medium to high	Strong	Medium	..
(*g*) Producers	Preferably low in amount and medium fusibility	Best size ¾ in. to 1¼ in. With suitable grates and feeding arrangement up to 30 p.ct. ¼ in. can be used	Low to medium	Medium	Free	..
(*h*) Water gas manufacture	Low in amount and high fusibility point	Large screened, uniform size, no smalls	Low to medium	Medium	Free to medium	..
(*j*) Blast furnaces	Low in amount, easy slagging	Medium, below 1¼ in., uniform in size	Low to medium	Strong	Free	Low sulphur
(*k*) Foundry work	Low in amount, easy slagging	Screened large, over 3 in.	Medium to high	Very strong	Medium	Low sulphur

The grading, dryness, and ash and sulphur contents of coke are all of considerable importance; but undoubtedly the most complex and least understood quality of coke is that relating to combustibility and reactivity. In the present paper, an attempt has therefore been made to discuss the fundamental considerations relating to combustibility, as it is only from such a basis that a scheme can be evolved for the production of coke of suitable combustibility and reactivity for the use to which it is to be applied. There is every reason to state that, in the past, the subject of the combustibility of gas-works coke has not received the care and consideration which the subject merits.

Combustibility and Reactivity of Coke—Definitions and General Considerations.

A clear understanding of what is meant by combustibility and reactivity is necessary. The terms must not be used interchangeably to define one property. Depending on the use to which a particular coke is to be put, one of two properties is required—namely, either the ability to combine readily with oxygen, or the ability to react with a substance other than oxygen. The term combustibility should be employed to connote the property of combining with oxygen, and the term reactivity to indicate the property of reacting with a substance other than oxygen. A further conception, that of ignitibility, is also necessary.

When coke is gently heated, and a stream of air is at the same time passed over it, on withdrawal of the source of heat, the coke mass cools down, and no combination of oxygen and carbon will have occurred. If the source of heat be maintained for a further period, and the coke be thereby brought to a higher temperature, slight combination of carbon and oxygen occurs; nevertheless, the coke mass will again cool down when the source of heat is removed. If, now, the source of heat be again applied, and the coke be brought to a still higher temperature, at a certain stage vigorous combination of oxygen and carbon occurs with a more or less sudden and spontaneous rise in the temperature of the coke to the point of incandescence, due to the large amount of heat liberated by the active combustion of the coke. Withdrawal of the external source of heat has now no effect in enabling the coke mass to cool down, and combustion will proceed, as long as the stream of air is passed over the coke, until the coke is completely burnt.

The ease with which coke can be brought, by the agency of an external source of heat, to the stage at which vigorous combustion occurs, is a measure of its ignitibility and a readily ignitible coke requires a lower temperature for incipient combustion than does a difficultly ignitible coke. Once combustion has commenced—and on the assumption that all conditions are standardized—the rate at which the coke burns is a measure of the combustibility of the sample.

A point which must be mentioned at this stage is that, in the past, considerable discussion has taken place as to the manner in which coke burns, and that it has been believed by many that combustion takes place in two stages:

$$(1)\ 2C + O_2 = 2CO.$$
$$(2)\ 2CO + O_2 = 2CO_2.$$

From the evidence now available, it appears that this view cannot be maintained, and that combustion takes place in one stage with direct formation of carbon dioxide.

$$C + O_2 = CO_2.$$

In connection with ignition, the occurrence of an ignition range must be referred to. This range is a temperature interval which commences at the temperature at which traces of carbon dioxide can first be detected when a stream of air is passed over the sample of coke, and extends to the temperature at which combination of oxygen and carbon is so rapid that the heat liberated is sufficiently great to cause a further rapid rise of temperature to the point of incandescence. During the ignition range, generation of heat takes place so slowly that the temperature of the coke does not rise appreciably; the heat generated being dissipated by conduction and convection to surrounding bodies. However, as soon as the end of the ignition range is reached, rapid combustion occurs, with a considerable rise in temperature.

Though individual samples of coke may show wide differences in ignition range, it may be doubted whether large differences in combustibility are encountered at high temperatures. It is likely that, at high temperatures, such as those ruling in blast furnaces, the combustibility of individual specimens will tend to be very nearly the same. Of course, coke intended for domestic use should be characterized by a low ignition range.

Reactivity may be considered from the aspect of affinity towards steam, carbon dioxide, or ferrous oxide. The first is of importance in connection with water gas plant, the other two in connection with blast furnace operations. In the blast furnace, a matter of prime importance is the securing of an atmosphere rich in carbon monoxide following immediately on the zone of active combustion of the coke. It has been mentioned that carbon dioxide is the first product of the combustion of coke. The action of the blast on the coke is to bring about active formation of carbon dioxide, and this must immediately be reduced by the zone of coke lying above the combustion zone, with formation of carbon monoxide according to the equation $CO_2 + C = 2\ CO$. The ease with which a sample of coke can react at a high temperature with carbon dioxide is a measure of its reactivity towards this gas. Since the reaction is an endothermic one, it is favoured by a high temperature, and it is necessary that combustion at the tuyeres be rapid, since, when this is the case, the amount of heat lost by radiation bears only a small proportion to the heat liberated by the combustion of the coke, and the mixture of nitrogen and carbon dioxide meeting the downcoming coke in the next zone will be at a sufficiently high temperature for CO production to occur rapidly.

Measurement of Combustibility, Reactivity, and Ignition Range.

Weyman's method of ascertaining the ignition range is a very convenient one. Air is passed through the sample at a standard rate, the temperature of the air being raised at a uniform rate of 10° C. per minute throughout the test. A thermo-couple registers the temperature of the coke. The air, having travelled through the coke, is passed into a weak solution of sodium hydroxide coloured with phenolphthalein. The temperature at which the first signs of formation of CO_2 are apparent—evidenced by an incipient fading of the colour of the alkaline solution—represents the commencement of the ignition range. From this point, readings of the coke temperature are taken at regular intervals; the air temperature still being raised at the standard speed. When a certain temperature, corresponding to the end of the ignition range, is reached, the temperature-time curve bends sharply upwards, and the stage is then reached where the heat of combination of the oxygen and coke is sufficient to raise the temperature of the coke mass to a point at which rapid combustion takes place with incandescence.

This test does not give any indication of the speed at which combustion proceeds once it has commenced. A test to provide information on this point is made use of by the Koppers Company of America. A charge of coke contained in a shaft, and resting on a grate, is heated by burners to a suitable temperature, and an air-blast is then directed into the charge under standard conditions and for a definite time. The weight of coke consumed during the test is a measure of the combustibility of the sample. This test, however, really indicates the sum of the combustibility and the reactivity, since in the case of a highly reactive coke the hot mixture of CO_2 and nitrogen resulting from the combustion of the coke above the grate reacts with the coke with which it comes into contact just above the combustion zone, and formation of carbon monoxide occurs, so that some of the coke is used up in accordance with the equation $CO_2 + C = 2\ CO$. A highly reactive coke will thus burn away twice as quickly as would a coke of zero reactivity. The test affords a very useful indication as to the suitability of a coke for blast-furnace purposes, since, for this application, high reactivity is required. For foundry work, on the other hand, very low reactivity is required, since, in order that high temperatures may be attained, the endothermic reaction just indicated must be eliminated.

Reactivity is generally measured by estimating the proportion of carbon monoxide formed in the issuing gas when a stream of carbon dioxide is passed under standard conditions over a definite weight of coke. A convenient temperature is 900° C. Some workers use a stream of oxygen, and determine the concentration of the two oxides of carbon in the issuing gas. In either case, a high $CO:CO_2$ ratio includes high reactivity, and a low $CO:CO_2$ ratio low reactivity.

It must be remembered, in connection with the properties under discussion, that coke is by no means homogeneous, and that, in the case of (say) coke-oven coke, a good deal of difference exists between the cauliflower end and the inner portion; the difference being in favour of the inside portion as regards combustibility, reactivity, and ignitibility. Hence, when large lumps are broken-down to provide a sample for a laboratory investigation of these properties, the resulting coarse powder is heterogeneous, and when the test is carried out portions of the sample will burn away more readily than the remainder. In such investigations a graded sample is, moreover, employed—for instance, only the portion between 10 mesh and 8 mesh in size—and the fact that the proportion of fines resulting when a large piece of cauliflower-end coke is broken-down is different from that resulting from the inner portion may lead to false conclusions.

Factors Influencing Combustibility, Reactivity, and Ignition Range.

Among factors which must be discussed are:

(1) The thermal treatment of the coal both during and after coke formation.
(2) The volatile content of the coke.
(3) The physical structure of the coke.

(4) The ash content of the coke.
(5) The size of the coke.

Broadly speaking, coke structure is fully developed before carbonization is completed, and further changes which occur in the charge result chiefly in the expulsion of additional amounts of volatile matter, and in an increase in the specific gravity, especially in the true specific gravity, of the coke. The coke at the same time becomes considerably harder. It is likely that this change in specific gravity represents a graphitization of the carbon, though the temperature ruling is never high enough for complete conversion into graphite. Long exposure to the temperatures nowadays prevailing during carbonization involves the production of a hard coke of high true specific gravity in all cases where the thickness of the charge is great, since the coke near the walls is inevitably maintained for several hours at a high temperature in order that the coal in the centre of the charge may be fully carbonized. Such coke is characterized by a high ignition range and a low reactivity; and in order to avoid these disabilities, and at the same time reap the advantages which high flue temperatures offer, modern coking practice tends in the direction of narrow carbonizing chambers. Thereby a more than proportionate reduction in the coking period is secured, resulting in the production of a coke of lower true specific gravity and higher reactivity.

As regards the physical structure of the coke, reference may be made to the size and distribution of the pores. Malleis has described four different types of cell structure:

(1) Very small cells with very thin walls.
(2) Large cells with thin walls.
(3) Small to medium cells with fairly thick walls.
(4) Large cells with fairly thick walls.

High combustibility and high reactivity may be expected to obtain when the cells are small and their walls thin. Indeed, experience shows this to be the case. The requisite structure is obtained in coke produced by the Sutcliffe-Evans process, and may be imitated by carbonizing blends of suitable coals without recourse to briquetting. The large surface exposed by innumerable small pores, compared with the small surface exposed by the same pore volume distributed about a much smaller number of large pores, is to a great extent responsible for the advantages which the former structure offers as regards combustibility and reactivity.

As regards the influence of a content of volatile matter, opinions are divided, and in some cases the views of investigators seem to be incompatible with the results obtained by them. Thus Weyman, in his paper on "The Combustion of Coke in One Stage," includes ignition range curves for a number of samples of coke, and states that in the case of samples of coke similar in all respects save that of volatile content, though their ignition range is higher with decreasing volatile content, these differences in the ignition range are not to be ascribed to differences in the volatile content. When such differences are actually observed, it seems somewhat unsound to attempt to explain away the observations; and it would appear that there is good cause for assuming that the higher the volatile content of a coke, the lower will be the ignition temperature, other conditions being the same.

In this connection, it must be emphasized that the actual differences between two samples of coke prepared under similar conditions are greater than would appear from their volatile contents. Coke prepared at temperatures below 1000° C. by no means consists only of carbon and ash. In addition to oxygen, nitrogen, and sulphur, notable proportions of hydrogen are present; and the gas obtained when the coke is heated during the volatile matter test consists mainly of hydrogen. The hydrogen is probably present in combination with carbon as a complex compound decomposable only at relatively high temperatures; and it is likely, therefore, that a coke which shows 1 p.ct. volatile matter at 900° C. contains upwards of 10 p.ct. of such complex compounds. This is readily conceivable, since hydrocarbons are known containing less than 5 p.ct. of hydrogen and more than 95 p.ct. of carbon. Thus, in the case of two hydrocarbons, pyrene and crackene, isolated from coal tar, we find:

Pyrene, $C_{16}H_{10}$, boiling-point above 360° C., contains 4·99 p.ct. of H, and 95·01 p.ct. of C.
Crackene, $C_{24}H_{12}$, boiling-point above 500° C., contains 5·92 p.ct. of H, and 94·08 p.ct. of C.

The case of crackene is mentioned in view of its remarkably high boiling-point. It is, of course, possible that in coke there may be present hydrocarbons with a boiling-point considerably higher than that of crackene, and these would suffer decomposition into carbon and hydrogen at temperatures below their boiling points. These hydrocarbons would probably be highly polymerized, and therefore insoluble in any of the usual solvents.

These considerations lead to the view that coke with a volatile content exceeding 1 p.ct. (as determined by a test at 900° C.) by no means consists exclusively of free carbon and ash. The increase in hardness and in true specific gravity which occurs when coke is maintained for a period of hours at high temperatures is probably accompanied by an increase in the amount of free carbon and in the formation of a variety of carbon with properties verging towards those of graphite. At the same time, the ignition range becomes higher and the reactivity lower.

It has been suggested that the thin film of graphite arising out of the decomposition of methane on the surface of coke may be responsible for a diminution in the reactivity of the coke. Calculations show that the amount of methane thus decomposed would provide a layer of graphite but a few molecules thick, and it is inconceivable that reactivity can be lowered through this slight thickness of graphite. On the other hand, choking of the pores through the decomposition of tarry vapours in the hot coke does adversely affect reactivity.

The rate at which a coke burns, or at which it reacts with, for example, carbon dioxide, is influenced by the grading of the material. Small lumps, of course, offer an advantage over large lumps, due to the larger surface exposed by the former in relation to their mass. On the other hand, the presence of breeze is unfavourable, since it impedes free circulation of the air or carbon dioxide; and the presence of a wide range of sizes is also unfavourable, since closer packing obtains under these conditions than it does when all the pieces are of approximately the same size. As is well known, dust of a combustible nature, when suspended in air, forms a highly explosive system, and powdered fuel is now extensively employed. Particles small in size are thus more reactive and more readily combustible than matter in bulk, though it is generally not possible to take advantage of this, since in producers or blast furnaces too great a back-pressure would result.

Apparent specific gravity also influences combustibility, since with a low apparent specific gravity a given mass of material exposes a larger surface than does a material of higher specific gravity. Hence vertical retort coke offers an advantage over horizontal coke, since the former has the lower specific gravity.

Recently attention has been drawn to the effect which constituents—previously regarded as inert—may have on the carbonizing process and on the resulting coke; and the addition of iron or of some of its compounds has been patented. It is claimed that the coke obtained shows enhanced combustibility and reactivity. Though, by suitable choice of the coal and of the carbonizing plant, cokes of high combustibility and reactivity and of low ignition temperature can readily be manufactured, and though plant is now available for making high-grade coke from coals which have previously been regarded as unsuitable for the manufacture of coke, developments such as this are of extraordinary interest, since they may lead to the production of a coke with a reactivity far beyond our present experience.

4.—FACTORS AFFECTING COKE QUALITY.

In the previous section it has been shown that coke for various uses requires definite properties, and that a coke suitable for one purpose may be unsuitable for another. The object of the present paper is to study the problem of coke manufacture from the point of view of the gas industry; and though coke is a factor of great importance, the production of gas of suitable quality for economic distribution cannot be sacrificed to produce coke. The question therefore arises as to what extent the various qualities of the resultant coke rest in the hands of the gas engineer, and also to what extent the gas engineer can vary the qualities of his coke, using the same coal.

Coke quality can be considerably affected by a number of factors, which may be divided into three classes—namely:

(*a*) Pre-treatment of coal, which includes de-ashing, grinding, blending, and stamping or briquetting.
(*b*) Selection of the correct type of carbonizing plant, comprising static or continuous charges, and using the best speed of heating and temperature.
(*c*) After-treatment of coke, which includes wet and dry quenching, and screening and cutting the coke.

All these operations are practicable, and, in fact, many are adopted to a certain extent in gas-works and coke plants in this country. In the great majority of gas-works, however, the coal is bought primarily for its gas-making qualities, and its preparation is confined to the conventional breaking to about 2-in. cube. The retorts used are admirable from the point of view of gas making, and the nature of the quenching and coke handling arrangements simple, rather than of highest efficiency. In these circumstances, the quality of the coke is more a matter of accident than forethought.

Contrast with this the process adopted at coke ovens, where a particular kind of coke is the desideratum. Coals are carefully selected, and ground or left in 2-in. size, as found to give the best coke. In many cases, coals of widely differing natures are carefully measured and mixed together. If necessary, the coal is stamped into a cake before charging. The type of carbonizing plant, the temperature of flues, and the

coking period are arranged to give the best results from the coke-making point of view, and, finally, the utmost care is taken in quenching and screening, so that the product is of the nature the customer requires. The inevitable conclusion is that, to attain an improvement in the quality of coke produced in gas-works, certain features of existing coke oven practice, and probably new features dictated by latest research, must be incorporated in the existing practice of gas-making.

In the following sections, the factors which have an effect upon coke quality are briefly considered. These factors are:

(*a*) Grinding and size of coal.
(*b*) Ash content.
(*c*) Coal constitution.
(*d*) Speed and duration of heating, and temperature.
(*e*) Static and flow carbonization.
(*f*) Internal heating, and the effect of gases.
(*g*) Blending and briquetting.
(*h*) The method of quenching.

Grinding and Size of Coal.

Lump bituminous coal consists of pure coal substance, together with shaley and other mineral matter. Four distinct varieties of the pure coal substance are known, and each is generally present in the majority of gas and coking coals in some proportion. These four constituents of the coal substance are generally found segregated in bands or pockets in the same lump of coal. One is definitely non-coking, and the others coking, with differing swelling and gas-making properties. In addition the shaley matter may also be found in bands and lumps, or, alternatively, finely disseminated through the coal mass.

Grinding the coal—and by grinding is meant breaking-down to pass (say) $\frac{1}{8}$ in.—allows of all these different constituents of the coal being intermingled. This leads to a more regular structured coke and an improvement in strength. The following instance bears out this statement. The same coal was used with the same flue temperatures and coking time in the same coke oven.

Size of Coal as Charged.			Shatter Test for Strength.
On $\frac{1}{4}$ in.		Through $\frac{1}{8}$ in.	Percentage left on 2 in. Screen.
18·0 p.ct.	..	57·9 p.ct.	42 3
2·0 ,,	..	86·9 ,,	50 0

The effect of grinding on the weight per c.ft. of the charge must be mentioned. Generally speaking, a coal ground to pass $\frac{1}{8}$ in. has a lighter weight per c.ft. than if the same coal were crushed only to (say) $1\frac{1}{2}$ in.; and thus the charge will be somewhat lighter. The difference may be 4 to 5 p.ct.

If blending of coals is adopted, then grinding is essential to effect adequate mixing of the constituent coals. Grinding to pass $\frac{1}{8}$-in. mesh is not expensive. The type of apparatus used generally is the hammer mill or Carr disintegrator, which can be obtained in large and small sizes. The power requirements can be taken as $1\frac{1}{2}$ H.P.-hour per ton. The particular degree of fineness which suits any coal is best found by experiment, but a large number of coking coals yield an improved coke by grinding to 85 p.ct. through $\frac{1}{8}$ in.

It would appear that the question of finding the most suitable size in which to charge the coal is not fully explored in gas manufacture. Particularly will it be more important with bulk carbonization in the direction in which modern ideas are trending. With horizontal retorts fine grinding may, unfortunately, be more limited, as there is a considerable volume of air enclosed with the charge, which will tend to give increased oxidation of the charge, and consequently a poorer coke. Especially will this be so with light charges. Nevertheless, it would appear that in adopting finer grinding of the coal, the gas engineer has to hand one method of improving coke quality.

Ash Content.

Though strictly not primarily under the control of the coke maker, the part played by this constituent of coal, as affecting the production of a cheap high-class coke, is of great importance. The buyer of coke requires heating material, and the ash he receives with his coke purchases is so much useless matter. It has cost the gas company extra carriage to transport from colliery to gas-works, and again from gas-works to consumer. It takes up valuable carbonizing space, and provides a nuisance on burning, in the form of clinker and of sulphur fumes. R. Lessing, in a recent paper, has shown that the carriage of mineral matter in the form of coal ash forms the second largest of any class of material carried on our railways. Apart from this enormous extra cost in transport, every per cent. of inert material charged into the retort results in a corresponding reduction in gas output, and increases in labour and fuel charges. These objectionable features of the ash problem are far outweighed by the psychological effect on the consumer by the high ash content of carbonized fuel.

Allied with the ash question is that of the sulphur content. In many cases a low ash coal is a low sulphur coal; and in high ash coals, where the sulphur is in the form of pyrites, a cleaning process, which reduces the ash, will generally reduce the sulphur content. The presence of iron compounds in the mineral matter in coke reduces its fusion point; and thus, added to the effect on coke prices, and to the sulphur fumes given off in burning, are mechanical troubles due to clinker formation in industrial and boiler furnaces.

The ash content plays a part affecting the strength of the coke which is often not fully appreciated. When coal is simply crushed to (say) 2-in. cube, the mineral matter is often left in fairly large pieces generally in the form of flat plates. These are never very firmly bound by the surrounding coke, and form planes of weakness along which the coke will fracture on dropping.

The effect of grinding finely will be to distribute the ash throughout the coal mass. In this form it is not liable to clinker, or cause a fire to go dead, as if it is segregated in bats, &c. It must be admitted that its more obvious appearance over the whole of the fire gives a false idea of the amount present.

To ensure obtaining low ash coals, it is the practice of gas engineers to purchase screened coal. This restricts still further the choice of coals for gas-making, and consequently increases the general price, whereas (and this is treated more fully under the section on "blending") the only hope of obtaining a cheaper raw material is to adopt processes which can use coals, non-coking, or nearly so, not utilizable with present methods of coke-making. Purchase of washed coals would give a low ash coke, but such coals generally contain 10 p.ct. of water, and the cost of carriage of this water, and its effect on throughputs and fuel consumption, prove a disadvantage. Drying the washery product in a centrifugal drier reduces the water content to 5 to 6 p.ct. The development of the recent methods of dry coal cleaning, which yield a product as dry as, or drier than, that obtained from the mine, is worthy of encouragement of all gas engineers as a solution of the problem of increasing the supply of clean coal.

Constitution of Coal and its Effect on Coking.

The present conception of the structure of coal substance is that it is a mixture of four physically separate constituents which have been termed fusain, durain, clarain, and vitrain; these being often recognizable as occurring in bands in the massive coal. Each of these constituents is regarded as consisting of an intimate complex of cellulosic and resinic matter, which may be separated into alpha, beta, and gamma compounds by the action of appropriate solvents at their boiling-point.

The alpha compounds, which are cellulosic in nature, and have been produced by prolonged degradation of cellulose and similar compounds, are insoluble in pyridine and in chloroform. The beta compounds are soluble in pyridine but insoluble in chloroform, and the gamma compounds, which are thought to be derived from resins present in the parent wood, are soluble in both these solvents. Since the gamma compounds are highly caking, and since coal from which the gamma compounds have been extracted is invariably non-caking, though a mixture of the extracted coal with its gamma compounds again acquires caking properties, opinions have been expressed that coking qualities are entirely a function of the content of gamma compounds. It has been stated by Illingworth that, among the coals, only those which contain at least 5·5 p.ct. of gamma compounds will yield a coke of good quality. To explain various differences which have been encountered in the coal series, it has been necessary to assume that there are four types of gamma compounds characterized by different thermal stabilities.

Foxwell, who, so far as is known, has carried out the most comprehensive investigation which has been made on the plastic state, was forced to the conclusion that there is no agreement between the percentage of gamma compounds and the caking qualities; and Bone has recently come to the same conclusion. Bone gives the main credit for the bestowing of caking qualities to another class of compounds—"humic" compounds—which, together with others, are extracted from the coal by superheated benzene at high temperatures (up to 285° C.). These compounds are characterized by their being insoluble in light petroleum and in alcohol; and according to Bone, resinic bodies such as the gamma compounds play a very subsidiary part in the coking of coal.

In view of what has been said, it will be apparent that precise knowledge is lacking as to what it is that makes a coal suitable for coke production; and for this reason and for others, it is preferable not to think in terms of something as arbitrary as matter soluble in pyridine and chloroform, but to ascribe caking power to the presence of "binders." Thus, a very strongly caking coal will have an excess of binder, a normal coking coal will have just about the right amount of binder, and a non-coking or feebly-caking coal will have an insufficient amount of binder, or the binder will be unsatisfac-

tory as regards binding power, due to its decomposition temperature being unsuitable, or to some other cause.

The Binder, and its Transformation during Coking.

It is to the presence of binders that such coals as yield good coke owe their caking and swelling properties. During the initial stages of carbonization, the binder fuses and is extruded from the coal as a tarry mass which, by virtue of its surface tension, spreads over the surface of the coal. At this stage there is a slight contraction in the charge as the extruded binder lubricates the coal, as it were, and enables the component pieces to pack more closely together. The binder is characterized by a very high volatile content, and is decomposed readily by heat, though not as quickly as the beta compounds, which have a much lower volatile content. The binder probably contains less oxygen and more hydrogen than does the coal as a whole. It is readily destroyed by the action of oxygen or oxygen-containing gases at temperatures even slightly above 100° C., and such destruction involves the loss of the coking properties of the coal of which it forms part.

It is the fusion of the binder which is responsible for the passage of the coal into the plastic state. Several investigators have carried out work in connection with the temperature at which coal assumes the plastic state, and the temperature at which the plastic state terminates. A few of the conclusions reached by Foxwell as a result of his extended investigations may be referred to. Foxwell found that, with very few exceptions, all coking coals pass through a plastic state between 370° and 500° C., but that in no instance was there any indication that plasticity began below 370°. In very few instances does the plastic state persist above 500° C., unless the rate of heating is very rapid. With fast heating, the plastic state extends over a longer temperature range, and the resistance to gas flow is greater than it is with slow heating. The temperature at which the plastic state commences is sharply defined, and is independent of the rate of heating. Anything which destroys the plastic matter before its purpose is accomplished, or which prevents its extrusion as a liquid capable of exerting surface tension, will prevent coking; and coals that yield poor coke or are non-coking have either insufficient or none of this plastic matter.

It may be mentioned that Powell, of the Koppers Company of America, has reported that the Booth Mine Coal of the Diamond Alkali Company was found to be exceptional in having a melting point as low as 325° C. Also, Schoefeld and Loring, who have worked on the swelling of coal, have found that the three coals examined by them had fusion points of 345°, 350°, and 355° C., but that in each case swelling commenced only at 400° C.

F. W. Sperr has found that the softening-point of most medium and high volatile coking coals lies between 350° and 370° C., though the softening temperature is sometimes as low as 320° C. The poorly-caking high-oxygen coals have a softening-point range of 370° to 390° C., and overlap with the low-volatile coking coals, which may have a softening point as high as 415°. The plastic range is given as 50° to 60°, though it is anticipated that a wider range will be encountered in some coals.

Figures obtained by Foxwell for some coals examined by him are shown in the following table. The remarks refer to the coking properties of the coals from the point of view of coke-oven practice.

Table showing the Plastic Range of some Coals.

Origin.	Volatile Matter.	Plastic State.			Remarks.
		Commences.	Finishes	Range.	
	P.Ct.	°C.	°C.	°C.	
Durham . .	?	370	530	160	At coking properties.
Durham . .	32·7	370	470	100	At coking properties.
Durham . .	?	370	460	90	Splint coal, used in coke ovens
N. Yorkshire	32	340	490	150	Strongly coking
N. Yorkshire	?	370	460	90	Not first class, but used
S. Yorkshire .	33·6	380	490	110	Good coking, bituminous
S. Yorkshire .	?	375	485	110	Good coking, bituminous.
S. Wales . .	24·0	370	470	100	Good coking
S. Wales . .	20·0	440	520	80	,, ,,
S. Wales . .	32·0	370	460	90	Bituminous, good coke, not strongly coking.
Leicester . .	34·9	Does not become plastic			Non-coking

The temperatures recorded by Foxwell and by other investigators have been included, so that some idea might be gained as to the plastic ranges of typical and abnormal coking coal.

Also, Charpy and Durant have reported the melting-points of a few coals, and find that the melting-point is independent of the volatile content, but is characteristic of the coal.

Illingworth, in common with other workers, finds that, in general, the melting-point of the binder increases with the C : H ratio of the coal—that is, as the anthracite end of the coal series is approached—and that the initial temperature at which a coal becomes plastic also increases with increase in this ratio.

Coke Formation.

When a coal is heated, as soon as a definite temperature, characteristic of the coal, is reached, some of the constituents melt, and the mass assumes a highly plastic state. If the plastic state continues over the stage at which gas evolution occurs fairly actively, the very viscous medium will not readily allow the gas to escape, and the mass swells up, and may even assume the form of a foam. As the temperature is varied, decomposition proceeds, and the viscosity is thereby increased still more, until finally coke is formed, and the inter-communicating cells of which it is composed will now allow gas to pass through them much more readily than would the plastic coal. Now carbonization at a particular temperature is by no means instantaneous, and a coal must be maintained at a certain temperature for a reasonable time before all the matter volatile at that temperature is evolved. It can thus readily be imagined that, with a heating rate sufficiently slow, gas generation will be so sluggish that the gas will have plenty of time to escape from the plastic coal. Under such conditions, swelling will not occur to nearly the same extent as it would if heating were more rapid. On the other hand, it is possible to heat coal so rapidly that the coal is converted into coke before swelling is able to occur. This, however, is not realizable when coal is treated in bulk, and is only applicable to very small-scale experiments in the laboratory.

In its conversion into coke, coal passes through a variety of stages. First the plastic state with gradually increasing viscosity, secondly into a soft coke, and finally into a hard coke. During the plastic stage, decomposition is proceeding, but the coal is relatively inactive as regards the evolution of large amounts of tar, which is given off most freely before the commencement, or after the conclusion, of the plastic stage. The formation of a hard coke commences at about 700° C., and extends through the range 700° to 800° C. During this period, the main volatile product is hydrogen, so that it is assumed that the intermediate soft coke is of the nature of a hydrocarbon mixture, which is subsequently resolved into hydrogen and carbon; the carbon being left as a hard coke. Hydrogen continues to be evolved at temperatures as high even as 1100° C., so that the production of a coke almost free from hydrogen requires a very high temperature.

When a charge of coal is carbonized in a static condition, such as in horizontal retorts or coke ovens, heat transference to the coal takes place solely through the walls forming the chamber in which the coal is confined; and after the charge has been in the carbonizing chamber for a certain time, there will be a complete gradation in the mass under treatment, ranging from a perfectly developed coke next to the walls to a completely untouched coal in the centre of the charge. We thus find, on cutting a section through the charge from the wall-side to the centre, first a layer of hard coke, and then successively layers of soft coke, plastic coal, and finally unaffected coal. Each part of the coal will pass through the successive stages, so that we have a plastic layer travelling through the coal mass from the wall to the centre of the charge. It has been mentioned that coal in the plastic condition is in a form approaching a foam; and it is the property of foams that they transmit heat very badly. One consequence of the plastic state has already been mentioned, and we now have the further disadvantage that the low heat-transmitting powers of the plastic layer are responsible for the carbonizing period occupying a much longer time than it would if the plastic stage were eliminated. It will be shown later that many investigators have found that there is a method of eliminating the plastic stage by making use of blends.

Speed and Duration of Heating and Temperature.

These factors are in many ways crucial, as they affect the strength, size, specific gravity, and combustibility of the coke.

Considering a static charge, the layer of coal nearest the wall receives heat very quickly, so that its temperature is raised to over 850° C. rapidly. On the other hand, the inside layers of the charge, being 6 in. and more from the walls, remain at a temperature below 300° C. for several hours before coking begins to take place. Thus, though the actual time taken for the temperature to rise from 300° C. to high temperatures may not be much different for any layer, the conditions are really very different, since the outer layers rise in temperature immediately on charging, and endure high temperature for several hours, whereas the inside layers are exposed for several hours to a temperature below 300° C., and are removed when they reach complete carbonization.

Effect of Duration of Heating.

This different treatment results in the coke formed in different layers having very different properties. In the first place, it will be found that the coke from the inner layers has a lower specific gravity, and is more combustible than that from the outer layers. Actual combustibility tests bear out this fact. The test used consisted in placing 125 lbs. of the coke, care-

fully sized, in a test furnace, starting combustion, and then passing through the coke a definite quantity of air in a definite time. The percentage of carbon burnt is taken as a measure of the combustibility.

It was found by carrying out tests on coke from the outside and inside layers of a coke oven charge which was coked in 22½ hours, that under the standard condition of air draught, the amount of carbon burnt was:

With coke from inner layers	94·5 p.ct.
,, ,, ,, outer ,, (wall coke) . . .	70·3 ,,

In other words, it was decidedly more difficult to burn the coke which had been exposed for several hours to high temperature. Over-coking is fatal to combustibility. If large coke is required, over-coking has another objection, as with many cokes long exposure at high temperature, by inducing excessive shrinking, splits the coke into small pieces.

Effect of Speed of Heating.

The actual speed at which the coal is raised in temperature is also of importance, particularly with coals which are not considered the finest coking coals. In this class are many coals used for gas making. It is found that rapid heating and high temperatures are the most favourable conditions for producing the strongest coke from coals not of the finest coking quality. This has been well established in experiments with fast coking ovens in America, using feebly coking coals, where the best coke is always obtained when the heat is transferred throughout the mass in the shortest time.

The gas industry is favourably placed with respect to both speed of heating and duration of carbonization. The horizontal retort, even with full charges, is burnt-off in 12 hours. In the adoption of other intermittent systems, such as vertical retorts, inclined chambers, and coke ovens, for gas making, the dimensions of these are arranged so that 12 hours' carbonizing time can be used; and with continuous retorts, the throughputs now attained mean that the coal is subjected to heating for a similar period. The above considerations have been made from the standpoint of high-temperature carbonization, producing a hard coke which is suitable for the majority of the purposes outlined in Table 3.

The desirability of producing a free-burning fuel for use in open grates has led to much discussion on the means of producing a coke containing 5 to 8 p.ct. volatile matter. Many projects have been put forward in which low flue temperatures have been used. There is no doubt that an easily ignitible free-burning fuel can be produced by this method, but low flue temperatures have resulted in slow heat penetration. In order to reduce the carbonizing time, the thickness of the charge has been reduced to 4 in. This has meant a multiplicity of charges for anything like a large output. Special plant is required, and a new difficulty is found in working the process on a satisfactory financial basis.

The question may be asked whether it is possible to produce in bulk, using high flue temperatures, a coke which will have a mean volatile content of 5 to 8 p.ct., this being produced preferably in existing types of carbonization plant. Experimental evidence would seem to show that the answer is in the affirmative.

The subject of blending is considered at length in another section; but here it may be said that a properly-blended coal allows of rapid heat penetration. In other words, the temperature of the inner layers will not lag far behind that of the layers nearest the source of heat, particularly if a narrow coal charge is adopted. This being so, difference in the volatile content of the inside and outside of the charge at any time will not be so great as it is with unblended charges.

The solution, therefore, of providing a coke with a mean volatile content of 5 to 8 p.ct., using high temperatures in the flues, is to carbonize blends of coal for periods considerably less than those required for complete carbonization, of the order of two-thirds duration, and by this means to produce a coke with a mean volatile content of (say) 7 p.ct., the outer layers having (say) 4 p.ct., and the inner layers 10 p.ct., of volatile matter.

The foregoing considerations may be summed-up as follows:

1. Long exposure at high temperatures increases the specific gravity and reduces the combustibility of coke. Rapid carbonization, by reducing the duration of exposure to high temperatures of the portion of the coal nearest the source of heat, tends to produce an easily combustible coke.
2. Rapid heat penetration, by avoiding degradation of the "binding" material, gives a better coke, especially from inferior coking coals.
3. High temperatures are therefore necessary to ensure quick coking.
4. Rapid heating tends to give a smaller, uniform-sized, and combustible coke; slow coking—large, denser, and incombustible coke.
5. If required, a coke containing 5 to 8 p.ct. of volatile matter can be produced by carbonizing blends with high flue temperatures for shortened coking times.

Static and Flow Carbonization.

The plants for the carbonization of coal on gas-works may be divided into two classes—those of the static type, in which the coal is not subjected to movement during carbonization, and the flow type, in which the coal is subjected to movement during carbonization. Of the first type may be mentioned coke ovens, horizontal retorts, inclined chamber ovens, intermittent vertical retorts. Of the second type may be mentioned externally-heated continuous vertical retorts, and internally-heated vertical retorts.

The type of carbonization plant has an effect upon the coke formed. In the static type of plant, as has already been pointed out, when ordinary coal is carbonized, a complete range from fully carbonized coke to uncarbonized coal may be found in the carbonizing apparatus. After two or three hours, a cross-section of the retort would show fully-coked material against the heating walls, and uncarbonized coal at the centre of the charge. Between these two extremes, as one proceeds inwards towards the centre, one would observe, next to the fully-carbonized coke, material already consolidated, but containing a high percentage of volatile matter, and, nearer to the centre of the charge, a plastic layer.

When coal is being carbonized under flow conditions, the same facts do not hold. In this case, there are two forces acting at right angles—the travel of the coal downwards, and the travel of the heat inwards.

During the carbonization of coal, either in the static or the continuous type of plant, only a comparatively small portion of the charge is in a plastic condition at the same time. It is during this stage, when the binder of the coal is melted, that the final satisfactoriness of the coke is largely determined; and thus there is a tendency for a coal which has only the minimum amount of binder to give a better coke in a static type of plant than in a continuous type.

Internal Heating, and the Effect of Gases.

Carbonization of coal may take place by means of the transmission of heat from the heated walls of the carbonizing chamber, or by means of hot gases, or by the combination of these two factors.

It has been shown that the difficulty in carbonizing coal of the type which normally gives good coke in an apparatus such as the coke oven is that there is a tendency for the part of the charge near the oven walls to be maintained at a high temperature for a considerable period, whereas the centre of the charge is maintained at a lower temperature. It has also been shown that coke maintained at high temperatures for long periods tends to become less combustible and less easily ignitible. From the point of view of combustibility of the product, there would seem little doubt that internal heating by means of sensible heat should give a highly combustible material. The difficulty arises in the fact that large quantities of hot gas or superheated steam have to be led through the material being carbonized, in order to convey the heat necessary to carbonize the fuel. If this sensible heat is carried in low grade gas, then the resulting gas from the internally-heated carbonizing plant is of necessity low grade, and unsuitable for distribution from gas-works. If the gas which is the heating medium is of high grade, then it tends to become degraded by passage through the material undergoing carbonization. Therefore, from the point of view of gas-works practice, it is difficult to devise a process of carbonization depending entirely upon internal heating by sensible heat.

In one type of existing carbonizing plant the heat is transmitted to the charge by a combination of the conduction of heat from the heating walls and sensible heat. This is the case in the modern types of continuous vertical retorts, working under steaming conditions. The coal in its descent through the retort is heated by the combustion chambers surrounding the retort. At the bottom of the retort, steam is admitted, which serves first to cool the coke, and then, by interaction with the coke, to produce water gas. This water gas, mixed with a certain percentage of undecomposed steam, passes up through the retort at temperatures usually exceeding 1000° C., and under suitable conditions of operation tends to carry out a considerable portion of the work to be done in carbonizing the coal. In a continuous vertical retort the hot gases passing up from the bottom also tend to clear out the traces of gases from the red-hot coke; and the high combustibility of coke from continuous vertical retorts is partly attributable to this sweeping action due to the water gas and steam in the lower portions of the retort. In a horizontal retort, the gas flow is essentially different from that of a continuous vertical retort. When the charge is put into a horizontal retort, a band of fully burnt-off coke is rapidly formed near the retort walls, and, as the heat penetrates inwards, this band of coke increases. Gas liberated from the coal all passes through the red-hot coke. This serves to crack the tars evolved, and at the same time deposits, on the surface of the coke, carbon from the cracking of the tars. In a continuous vertical retort, on the other hand, the coal during its main passage in the retort reaches increasing temperatures, until it is fully carbonized, and then, as coke, passes through decreasing temperatures until it is relatively cool. During this cooling stage, the coke is cleaned up by means of the steam.

Blending and Briquetting.

At the present time gas undertakings draw their supplies of coal from the class known as "gas coals." These are caking coals, and generally yield a coke more swollen and less hard

than that obtained from the best coking coals. These coals are selected on account of their gas-making properties and the fact that they yield a coherent coke.

It has been known for many years that "inert" material such as coke dust, sand, &c., could be mixed with most of the coking coals; the mixture when carbonized yielding a good coke. It was also found that coals classed as non-coking coals, including anthracite, low-volatile steam coals of South Wales, and high-volatile steam coals of Northumberland and Yorkshire, could similarly be incorporated with caking coals.

Charpy and Godchot, J. Roberts and S. R. Illingworth, among later workers, have shown the technical advantages of blending with the raw caking coals suitable proportions of such materials as coke dust, anthracite, and non-coking bituminous coals.

The main effects are:

(*a*) A harder coke.
(*b*) A more combustible coke.
(*c*) Quicker heat penetration of the charge.

These effects follow from the fact that in ordinary caking coals there is generally an excess of the material which acts as a "binder" during the coking process. These "binding" substances during the early stages of heating melt, and cause the pastiness noticed when coking coals reach temperatures of between 300° and 500° C.

This pasty stage is resistant to the transference of heat, since the binding substances absorb heat in their decomposition, and also prove a barrier to the free circulation of the gases evolved from the portions of the coke which have already reached a higher temperature. This excess "binding" material is also the cause of the large pores which are the result of the gases generated during its decomposition forming bubbles in attempting to escape from the pasty layer. The drawn-out walls of large pores are weak, and highly swollen coke generally suffers by abrading. If, by the addition of non-coking material, the excess "binder" can be utilized, then the pores become regular and smaller in size. The thin walls of the larger pores are replaced by a greater number of thin walls of the smaller pores, making for a harder and more combustible coke.

Application to Gas-Works Practice.

Consideration may now be given to directions in which this operation of blending can be applied with advantage on a gas-works. Four schemes are discussed in the present paper, two of which can be adopted in any existing intermittent carbonizing apparatus. The third, mainly applicable to coke ovens, appears to offer a solution to the question of producing a free-burning smokeless fuel. The four schemes are:

(*a*) Blending coke dust with gas coals.
(*b*) Blending non-coking coals with coking coals; the mixture being charged loosely in the retorts, &c.
(*c*) Scientific preparation of the coal by grinding, mixing, blending, and compression before carbonizing.
(*d*) Briquetting the blended coal, using pitch as a binder, into small ovoid-shaped blocks for carbonizing in continuous vertical retorts.

Utilization of Coke Dust.

In ordinary carbonization, it can be taken that at least 10 p.ct. of the coke made is breeze, which can be disposed of only at low prices—much lower than its heating value warrants. By adopting means to return this to the coal stream, it should be possible to eliminate the breeze now requiring to be sold. Most gas coals are able to "absorb" more than the 7 p.ct. by weight (on the coal) represented by the present breeze make. Selling this as breeze at 10s. per ton brings in about 8½d. per ton of coal treated. Sold incorporated in the coke at 30s. per ton brings in 2s. 1½d.—an increased credit of 1s. 5d. per ton of coal carbonized, or 0·24d. per therm of gas made.

The chief precautions to be taken are in crushing the breeze finely enough—at least to ¼ in.—and in distributing it evenly through the coal. The mixing could be arranged to take place at the boot of the coal elevator, and the alterations necessary (a breeze hopper, crushers, and proportioning table) would not cost, in amortization of capital and wear and tear, more than 3d. per ton of coal carbonized, or 0·04d. per therm, leaving a net increased credit of about 0·2d. per therm.

Utilizing Non-Coking Coals.

A fuller scheme of blending is that of mixing-in as much non-coking coal as the coking coal will take. The following description of a large-scale test will indicate what may be achieved. The test was carried out in a coke oven, and the coals used happened to be on the works, and were in no way specially selected. The coking coal used was a well-known South Yorkshire nut coal of good gas-making and coking qualities. The non-coking coal was a Warwickshire nut coal specially bought for producer work. When carbonized alone in horizontal retorts, it yielded a friable coke, the greater proportion of which was pea size, and less. The two coals were roughly proportioned by shovelling into a heap; the proportions being 70 p.ct. of coking coal, and 30 p.ct. of non-coking. This mixture was passed in the usual way through a Carr disintegrator, which ground it to pass ½ in. and then completed the mixing. The mixture was then charged into a coke oven through the top doors. The coke obtained was well knit together, and hard, with regular small pores. The coking time for complete carbonization was 16 p.ct. less than the normal period with an unblended coking coal. It was possible to remove the coke from the oven before the charge had been completely burnt-off, as the addition of non-coking coal reduced the swelling of the charge, and a coke with an average volatile content of 5 p.ct. was thus obtained. This latter, when broken to less than 2 in., could be lighted in an open grate from paper and chips.

Lest it should be considered that blending is impracticable, it may be stated that there are dozens of coke oven plants in America, and on the Continent, where high-volatile and low-volatile coals, or lean and fat coals, are mixed in definite proportions. This is done on a small, as well as a large, scale. The arrangements are along the following lines:

The two classes of coal are received in a track hopper, broken to 1½ in., and delivered to their respective bins in the coal-breaker house. The outlet of each bin is provided with a measuring device, which may be a revolving table fitted with a plough which can be set to scrape-off coal at the required rate, or a short band conveyor, the thickness of the coal on which is regulated by a gate. The measured streams of coal meet, and may be delivered direct to the bins on the ovens to be charged, or, alternatively, pass first through a grinding mill, if it is desired to charge the coal in ground form. The extra cost of blending and grinding would not be more than 4d. to 5d. per ton, which would allow of amortization of the extra cost of mills and hoppers, and the power and wear and tear; and this can easily be recouped by an improved price of a few pence per ton of coke, or by being able to purchase cheaper non-coking coals.

Most gas-works buy several varieties of coal, some of which yield an inferior coke. The usual method of coal handling, in which no steps are taken adequately to mix these with the good coals, result in their being charged into the retorts without any attempt at blending—poor coke being the result. A blending arrangement as described above would without doubt effect an improvement in the coke from the coals at present being bought. It would also allow of still poorer coking coals being purchased, widening the field from which gas coals are drawn; and thus the pressure on the usually restricted gas coal market would be relieved.

Production of a Free-Burning Smokeless Fuel.

So far we have considered blending in the simplest manner which can be adopted, by installing the proportioning and mixing devices on existing plants. The amount of non-coking coal which can readily be blended with any given coking coal depends on the nature of the latter, and also on the speed of heating. The quicker the heat can be passed into the charge, the more non-coking coal can be used. A third factor, influencing the amount of non-coking coal it is possible to use, is that of compressing the charge. It is found that, after the blend has been prepared, if the material is crushed and compressed, thus excluding the air, and bringing the particles of coal into close contact, a greater proportion of non-coking material can be used.

Stamping wet coal is adopted in many coke-oven plants, particularly in Yorkshire, to obtain strong coke from the higher volatile coking coals. The coal, generally containing 10 to 12 p.ct. of moisture, is ground to ¼ in. size, and stamped in a box, forming a cake which is pushed into the coke oven. An outline of a scheme for preparing a free-burning smokeless fuel at high temperatures, with a satisfactory gas yield, may briefly be described as follows:

Coking coal is ground to a fine state of division, and is incorporated by mixers with non-coking coal crushed to 10 mesh, water being added. This, having been adequately mixed, is stamped in the usual way, and charged as a cake in a coke oven. By this means, non-coking coal up to two-thirds the amount of the mixture has been used. The coke produced has a very fine grained structure, which under the microscope can be seen to consist of a great number of fine pores with very thin walls. It has a very high mechanical strength, and is pushed from the oven with little breeze. Its combustibility, judged by the ease with which it lights in the open grate, and retains a cheerful fire, is remarkable.

The fuel is a high-temperature product, and does not depend for its free-burning properties on volatile matter, but on its particular structure. The fuel has been produced in existing coke ovens, using existing stamping machines. As examples of the mixtures used there are:

A. Two-thirds dry Welsh steam coal (non-coking).
One-third coking smalls.
B. Two-thirds Yorkshire non-coking.
One-third Yorkshire Silkstone.

A report on fuel "A" stated that it was capable of standing transit without much detrition. "It lasted 20 p.ct. longer than a similar weight of coal, and heated to a greater degree every part of the room where the fire was burning. It had the advantage of igniting readily from sticks. As an industrial fuel, where smoke is not permitted, it would be very good, as it could be driven easily. For grills, &c., it would be excellent."

The advantage of such a process, apart from the excellence of the solid product, is that it can be carried out in standard types

of apparatus. The coal preparation is effected in grinding and pulverizing machines and mixers, all of which are on the market. The carbonizing apparatus can be any in which cakes can be inserted, such as coke ovens and horizontal retorts. The former is the most obviously advantageous, as stamping machines are also a standard construction. The flue temperatures required are normal high temperature, 1300° to 1400° C., and coking times are adopted either to give complete carbonization or to leave 5 to 8 p.ct. of volatile matter, depending on whether the full amount of gas and residuals are required. The coking times are up to 25 p.ct. shorter than those necessary with an equal thickness of unblended coals.

The yield of gaseous therms will depend on the actual coals used in the blends. For example, the blend "A" above, since the dry steam coal had a low volatile content, gave a fuel yield of 80 p.ct. of the coal carbonized. With the mixture "B," both blends being high volatile, the coke yield would be the same or slightly more than with Yorkshire gas coals, and the gas and residual yields the same or slightly less.

The cost of necessary preparation is estimated to be less than 3s. per ton of coal, including amortization of capital, this being offset

(*a*) by using somewhat cheaper coals,
(*b*) by reduction in coking time, which affects labour charges and fuel consumption, and, in the case of a new plant, a lower capital cost per ton of coal carbonized.

With such a fuel, distinct in appearance, and superior in burning properties, a good sales organization would be able to build-up a demand at prices in excess of best coke prices, and certainly in excess of the average price received by the gas-works at the present time.

Briquetting for Continuous Vertical Retorts.

The process of blending has been treated from the point of view of static charges. It remains to examine how the advantages to be gained from incorporating non-coking coals and breeze with coking coals can be obtained, using the continuous vertical retort. Charging the blend loosely is not satisfactory, as the finely-crushed coal causes back-pressure to the passage of gases up through the retort. In addition to this, the continual movement of the charge would not allow the constituents to be bound firmly together, and there is a possibility that segregation of the constituents will take place, and a true blend will not be preserved. It is not possible to charge a cake, but, by briquetting, the mixture may be introduced in convenient form. 1½ to 2 oz. ovoid briquettes are a suitable size.

E. V. Evans, in the Cantor Lectures for 1924, has described the results of making 2-lb. briquettes produced by compressing finely-ground blends under a pressure of 10 tons per sq. in. The mechanical difficulties in carrying-out this on a large scale are great, and the cost is considerable. In the patent fuel industry, briquettes are made on a large scale, using pitch as a binder; and as this material is a product of coal carbonization, the application of briquetting to carbonization in continuous vertical retorts, using pitch-bound briquettes, introduces on the mechanical side no new and untried factors.

The process requires that a coal-briquetting plant be installed, in which the coking coal, non-coking coal, and breeze are tipped in the usual way, and delivered to hoppers, from which the required proportions for the blend are measured out by tables, screw conveyors, or belts. These meet each other in another conveyor, which receives the due proportion of finely-ground pitch. The mixture of coal, coke dust, and pitch is then passed through a disintegrator. The mixture is heated by steam, and kneaded into a homogeneous sticky mass, which is fed between the rolls of an ovoid press. In passing between the rolls, the material is moulded into the form of ovoids under a pressure of about 2 tons per sq. in. The amount of pitch used is 4 to 5 p.ct. As the briquettes fall from the rolls, they are cooled on an open wire belt conveyor, and are conveyed to the ordinary hoppers of the continuous vertical plant. From this, they are fed in the usual manner into the auxiliary hoppers, and descend into the retort as the coke is extracted.

The advantage of carbonizing coal in briquette form is, first, a largely increased throughput, owing to more rapid heat penetration. This reduces capital costs, labour costs, and fuel consumption. Secondly, there is an increased yield of gaseous therms—*i.e.*, gas and tar. This occurs not only from the ease with which the volatile matter escapes from the blended coal, as has been well explained by E. V. Evans (*loc. cit.*), but the pitch also contributes 3 to 3·5 gaseous therms per ton of briquettes.

It will be found that the scheme is self-supporting as to the supply of pitch. In the ordinary carbonization of coal, the pitch obtained is generally about 3 p.ct. by weight of the coal. The extra tar made when blends of coal are carbonized, and the tar produced from the carbonization of the pitch used as the binder, supply the additional small amount of pitch to enable 4 to 5 p.ct. to be used in the briquetting process.

Summary.

Blending of coke dust and non-coking coals with coking coals has the following advantages:

1. Breeze ordinarily made when using unblended coals can be eliminated, and all the coke will sell at the price of good coke. The large credits thus obtained will reduce the price of gas by an appreciable amount.

2. The gas undertaking now restricted for the supply of coal to the gas coal market can draw also from the steam and house coal (non-coking) markets. The possibility of buying cheaper varieties of coal is thereby greatly improved.

3. When carried out in a controlled and efficient manner, blending increases the strength and improves the combustibility of coke. Greater throughputs can be obtained, since the heat penetration through the charge is considerably increased, thus reflecting in reduced operating costs. Greater yields of volatile therms (gas and tar) per ton of coal are generally obtained, and the factor which decides whether the increase is obtained as gas or tar depends on the amount of cracking to which the products are subjected in the particular retort or chamber.

4. Successful blending is assured by:
   (*a*) Rational selection of the constituents of the blend.
   (*b*) Suitable grinding to ⅛ in. if necessary.
   (*c*) Controlled proportioning.
   (*d*) Adequate mixing.
   (*e*) High temperature and rapid heating.

Additional advantages can be obtained by stamping or briquetting.

5. As practical propositions, the following four schemes are immediately available:

I. Returning the breeze made to the coal circuit.
II. Blending non-coking coal and breeze with coking coals in suitable amounts, the mixture being charged loose into existing types of static carbonizing plants such as horizontal retorts, intermittent vertical chambers, inclined chambers, and coke ovens. Rapid heating is essential to this scheme.
III. Blending and forming the mixture into cakes before charging—mainly applicable to coke ovens.
IV. Briquetting the blends with pitch as a binder into 2-oz. ovoid briquettes for carbonizing in continuous vertical retorts.

6. The plant required—grinders, proportioners, mixers, stamping and briquetting machines—is standard apparatus in commercial use.

7. The maximum cost of the most elaborate of the above schemes of coal preparation is not greater than 3s. per ton of coal handled (allowing for interest and depreciation on the extra capital involved), and this outlay can be more than recouped by better coke quality, use of cheaper coals, elimination of breeze for sale, increased yields of gaseous therms or coke, according to the coals used, and lower operating costs on the retorting plant, owing to increased throughputs.

Method of Quenching.

In the early days of the gas industry, quenching consisted merely in putting sufficient water on the coke to prevent its firing, very little importance being attached to the amount of water used in quenching—this, perhaps, not being totally unrelated to the fact that coke *ex* works is sold by weight. In recent years, however, particularly since the development of the use of coke for industrial purposes, and since the placing on the market of dry coke from continuous vertical retorts, more attention has been paid to the problem of quenching. There is no doubt that, from every point of view, coke should be delivered to the yard as dry as possible, and that much of the prejudice which has grown up concerning its use has been due to the uneven quenching to which it is subjected, and its consequent unequal combustibility. Quenching of coke comes under three headings:

(*a*) Quenching by water.
(*b*) Quenching by means of inert gases.
(*c*) Quenching by steam.

Coke absorbs water to different degrees, according to the temperature of the coke when quenched. Thus, when quenched in a red-hot condition, it will absorb more water than when water is applied to it when it is cooled. Quenching when the coke is red-hot tends to fracture it and increase the percentage of breeze.

The most efficient method of quenching would seem to be to utilize the heat in the coke for the manufacture of water gas, the heat being taken from the coke before the latter leaves the carbonizing plant. Of the various types of carbonizing plant used on gas-works, the only one in which this can be applied is the continuous vertical retort; and the process is already used in a large number of plants in this country. Steam is injected at the base of the retort, and absorbs the heat from the descending heated coke, being superheated sufficiently to give a satisfactory water gas reaction. The coke leaves the bottom of the retort at a temperature sufficiently cool to prevent firing, in a perfectly dry, clean, condition, and in a form suitable for screening with the maximum efficiency.

Within recent years, various schemes have been put forward for the quenching of coke by means of waste gases; the installation working in conjunction with waste-heat boilers. Plants for the Sulzer process have been erected, and are giving very satisfactory results. In this process the red-hot coke is discharged into an airtight chamber, and cooled by passing

inert gases through it; the gases being cooled by the transference of heat to the tubes of a boiler plant. The steam production per ton of coke quenched by this process varies from 850 to 1000 lbs.

Where water quenching is essential, the supply of water should be the minimum rather than the maximum. There is little doubt that the general sale of dry coke, while it might lead to the sale of smaller total tonnage, would lead to an increased price per ton. A consumer receiving coke containing 15 p.ct. of water not only pays for the transport of the water, and for the labour entailed in feeding this extra bulk of material into his furnace, but he also requires more fuel in order to evaporate the moisture present in his coke.

The general conclusions are thus:

(1) Coke should be dry after quenching.
(2) Whenever possible, the heat from the coke should be used for making gas or for raising steam.

5.—TESTING OF COKE.

The analysis of coke as generally carried out involves merely the determination of the proximate composition of the sample—that is to say, moisture, volatile matter other than moisture, and ash. From the proximate analysis, the calorific value can be calculated with a reasonable degree of accuracy, though when a very high degree of accuracy is required combustion in a calorimetric bomb is necessary. A short description follows of the methods used for carrying out these tests, as well as for undertaking other tests which are also in many cases necessary.

Moisture is estimated by determining the loss of weight suffered by the sample when it is brought to constant weight in an oven maintained at 105° to 110° C. The sample should be as large as can conveniently be dealt with, and in some instances a sample as large as 5 lbs. may be treated, in which case the temperature may be raised as, but not higher than, 200° C.

Due to the hardness of coke, grinding should never be carried out under conditions in which a rubbing action can occur, since the sample will be contaminated with the material with which it comes into contact. An impact grinder or a ball-mill is desirable, or, where the latter is not available for the fine grinding required for analysis, a hard steel diamond mortar may be used.

For the determination of all constituents other than moisture, the sample should be ground to pass a 60-mesh sieve, and the ground product should be reduced to a convenient quantity (say, 50 grammes) by quartering or riffling.

Volatile Matter.—From the loss of weight suffered by 1 gr. of the sample when heated for 7 minutes at 925° C. in a platinum crucible provided with a well-fitting capsule cover, the moisture content of the sample is deducted, and the remainder of the loss in weight represents the volatile matter. The volatile content may also be determined on a dried sample.

Ash.—This is determined by incinerating 1 gramme of the sample at a temperature of 925° C. with free access of air.

Sulphur is estimated by the well-known Eschka method. A determination of the sulphur content is often required when the coke is to be used in the blast furnace.

Phosphorus is determined in the ash of the coke, and, in order that sufficient ash may be available, 5 grammes of the coke must be incinerated. The ash is evaporated with nitric and hydrofluoric acids, and fused with sodium carbonate. The melt is extracted, and any residue is again fused with soda. In the united extracts after acidification with nitric acid, the phosphorus is precipitated as ammonium phospho-molybdate, which is filtered, washed, and titrated against standard sodium hydroxide solution.

A knowledge of the phosphorus content is necessary only in special cases where coke of low phosphorus content is required for metallurgical operations.

Fusion Point of the Ash.—About 7 grammes of ash is required. This is moulded into a cone of the shape of a Seger cone by the help of a solution of dextrin, and the fusion point is determined by comparison against Seger cones in a suitable furnace.

A knowledge of the fusibility of the ash is desirable when the coke is to be used in producers or in water gas plant.

Calorific Value is determined by the combustion of about 1·25 grammes of the coke in a calorimetric bomb of the Mahler-Cook type, or in a similar apparatus. Since there is sometimes difficulty in securing complete combustion of the coke, even when a pressure of 40 atmospheres of oxygen is employed, it is preferable to weigh out 1 gramme of the coke, and to moisten this with a weighed quantity, about 0·25 gramme, of a lubricating oil of known calorific value. From the number of calories liberated in the combustion, the calories provided by the oil are deducted, and the remaining heat represents the calories available in the coke.

Porosity and Specific Gravity.—The porosity is calculated from the true and apparent specific gravities. The apparent specific gravity is determined by noting the weight of water displaced from a vessel full to overflowing when a known weight, preferably about 25 lbs., of the lump coke is lowered into the water. The coke must be removed from the water and re-weighed so that the weight of water absorbed by it may be determined, and added to the weight of the water displaced, to enable the true displacement to be arrived at.

The true specific gravity is obtained by grinding the sample to pass 200-mesh, introducing a known weight of the ground powder into a weighed specific gravity bottle, covering with water, and boiling to displace air from the minute pores. The bottle is cooled, filled to the mark with water, and weighed.

If W = weight of dry coke.
W_1 = weight of bottle + dry coke + water required to fill bottle.
P = Weight of bottle + water required to fill bottle (when no coke is present)

then, true specific gravity $= \frac{W}{W + P - W_1}$.

Porosity is always expressed as the percentage by volume occupied by the pores, and is calculated from the formula

$$\text{Porosity} = \frac{100\ (\text{true specific gravity} - \text{apparent specific gravity})}{\text{true specific gravity}}.$$

Shatter Test.—This test is useful, as it provides information as to the liability of the coke to break-up when it is handled. 50 lbs. of the coke in the form of lumps of a size such that none will pass a screen of 2 in. square mesh is placed in a suitably-mounted box which has a bottom consisting of two hinged doors which can be unlatched, thereby enabling the contents of the box to drop out through a height of 6 ft. on to an iron plate. The coke is dropped four times, being gathered up and replaced in the box after each stage. Finally the sample is screened through square mesh sieves of apertures 2, 1½, 1, and ½ in., and the percentage of each of the five fractions is noted.

Crushing Strength.—The crushing strength of coke may be determined by use of a testing machine such as is used for testing concrete, and is expressed as the load, in lbs. per sq. in. of the cross-section of the test piece, at which crushing occurs. A test-block is cut from the coke, and the sides are ground flat and parallel. The dimensions of the ends are measured, so that the cross-section may be calculated. The test block is placed in the machine, and the load is uniformly increased until failure results.

Visual Examination.—Each consignment of coke is inspected with a view to ascertaining its general suitability for the purpose for which it is intended. Inspection serves to indicate whether carbonizing has been complete or too protracted, and whether the grading is suitable. It also enables an idea to be formed as to the liability of the coke to fracture; and indications as to hardness may be obtained by testing selected pieces with the point of a knife. Cut sections of the coke may then be studied, and these provide information as to the presence, or absence, of excessive amounts of spongy coke, and as to the structure of the cell system.

In connection with the testing of coke, the specifications of the American Society for Testing Materials may, with advantage, be studied, particularly specifications Nos. D 37-21, D 141-23, D 22-23, and D 167-23T.

6.—STUDY OF COKE STRUCTURE.

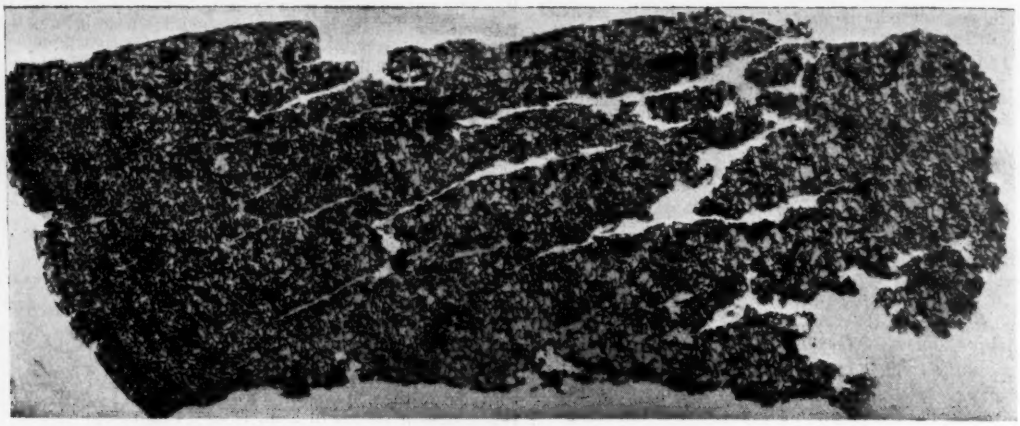
1. Preparation of Coke Sections for Visual Examination.

The examination of a lump of coke as to its texture is normally a difficult matter, if it be desired to obtain an idea as to the size and shape of the pores, the wall thickness, and the general uniformity of the specimen. The problem has, in the past, been tackled by the examination of micro-sections by transmitted light; but these are usually much too small, and if a piece of furnace coke is under examination it is necessary to examine more than one section to obtain information as to the structural differences existing in the cauliflower end, the centre, and the inner end. For this reason hand sections also are examined; but here there is a drawback—that the shaded air pores do not show up well against the coke skeleton, and one cannot form a mental picture of the structure.

With these defects in mind, Dr. Rose, of the Koppers Company of America, has developed a very ingenious method for revealing the details of coke structure in a beautiful and illuminating manner. Essentially, the method consists in filling in the pores and cracks of a plane section of the coke with a suitable white cement, and polishing the surface so obtained. By this means, the cell walls of the coke are rendered visible in delicate tracery against a strongly contrasting background, and the section lends itself readily to a critical examination by the aid of the naked eye, a lens, or a microscope. Inert constituents such as shale and dirt are rendered visible to a striking degree, and in suitable instances even the structure of the vegetable matter from which the parent coal was derived is revealed. Further, minute pores in the cell walls are exposed to view. Needless to say, such a section lends itself admirably to photographic reproduction, either natural size or considerably magnified, and sections may be made from large pieces of coke.

Working details of his method were very kindly supplied by Dr. Rose, and a description of the procedure is appended. It has been found possible to amplify his description by the inclusion of more detailed information on some of the manipulative features necessary for securing the best results, based on the experience which has been gained during the preparation of a number of sections of the type about to be described.

Photographs of sections prepared by this method have appeared in the Fourteenth Report of the Research Sub-Committee



Filled-in Section. Coke from Scotch coal produced in 14-in. oven, with 11 hours 40 mins. coking time.

of the Gas Investigation Committee of the Institution of Gas Engineers (1925). At the annual meeting at which the above report was presented, Dr. Lessing referred to the publication of photographs of coke sections filled-in with paraffin wax in his paper in the Transactions of the Institution of Gas Engineers for 1912; but a comparison of the two sets of photographs shows that, for brilliancy of detail, the method evolved by Dr. Rose is incomparably superior to the paraffin wax method.

Description of the Process.

Apparatus and Materials Required.

1. An elastic carborundum wheel. Thickness, $\frac{1}{16}$ in. Diameter, 10 to 12 in.
   The wheel is to be fitted in suitable bearings so as to revolve in a vertical plane at a rate of about 1500 r.p.m.
2. High-grade plaster of Paris, passing 200 mesh, and preferably air-separated. It should be absolutely white, and of the fineness specified.
3. Light magnesia of good quality.
4. No. 280 carborundum powder.
5. 10-minute carborundum powder.
6. 30-minute carborundum powder.
7. 60-minute carborundum powder.
8. Levigated alumina.
9. Suitable pieces of wood for forming the moulds.
10. A ground-glass plate about 12 in. square.

One pound of No. 280 carborundum powder will suffice for a large number of sections, while, of the finer grades, a quarter of a pound of each will be ample.

The Method.

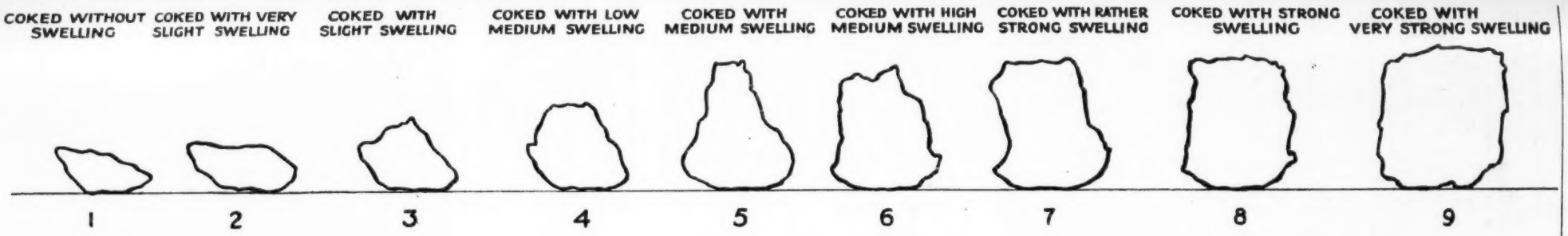
A typical lump of the coke is split longitudinally by the aid of the cutting wheel (or, if this be not available, a hack saw may be employed), and one of the resulting sections is mounted in plaster. (The remaining section may be submitted to analysis or to any other tests.) The plaster is intimately mixed with 2 p.ct. of its weight of light magnesia, to retard the setting time sufficiently for working purposes. It is necessary to adjust the proportion of magnesia nicely, and to use a fine plaster. The mixture is made into a moderately stiff cream, by gradual addition of water to the extent of roughly 45 p.ct. by weight, and the mass is well worked, by kneading it by hand, to ensure freedom from lumpiness. Care should be taken to avoid the introduction of entrapped air. A mould of suitable size with movable sides is prepared, and its inner surfaces are smeared lightly with grease or soft soap. The cement is filled into the mould, and the section of coke, previously freed from dust with a strong jet of water, is inserted so that its cut surface is flush with the upper surface of the cement. The cement is allowed to set, a period of about 30 minutes generally being ample if the atmosphere is warm, and is then left for an hour to harden properly. As is well known, plaster sets rather rapidly, and the procedure outlined above must therefore be carried out fairly expeditiously. After the cement has set, a hard block should be obtained, and this may then be removed from the mould.

The exposed coke face is again washed, and a paste of plaster-magnesia mixture and water is rubbed well into its pores with the finger tips, and then washed off. This is repeated until the paste no longer becomes grey. A fresh quantity of the paste is then worked-in and allowed to harden. The coke face is then trued by grinding it on a ground-glass plate with the No. 280 carborundum powder. Grinding is continued until the entire surface is flat, and if the filling material has become grey, it is washed-off and renewed. During all the grinding operations, the glass plate should be kept well flushed with water, as this prevents the filling material from being sucked from the pores. The section is then ground successively with 10-minute, 30-minute, and 60-minute carborundum powder; and after each stage fresh paste is worked-in and allowed to set, if inspection through a lens or microscope shows that any of the pores or minute details are not filled-in. Care should be taken to wash away all traces of any grade of carborundum before proceeding with the next grade. In carrying out the grinding, the surface should be rubbed down only sufficiently just to remove the surface layer of plaster, otherwise new coke pores are exposed, and will require to be filled in. After the washing which follows on the finest carborundum powder, the surface is again filled-in, and, the plaster having set, the surplus is removed, and the section polished by grinding on the ground-glass plate without the use of an abrasive, but with a liberal amount of water. Immediately before the final polishing, levigated alumina may be used on the glass plate with the water. However, this is not absolutely necessary if the previous treatment with the finest carborundum is properly carried out.

Throughout, progress is constantly controlled by examination of the coke section under magnification.

Finally, when a highly-polished section in black and white has been obtained, the specimen should be allowed to dry completely in a warm place, otherwise moisture will continue to sweat out when the specimen is preserved.

Cut Section. Coke from Durham coal pulverized to 85 p.ct. through ⅛-in. mesh, produced in 14-in. oven, with 11 hours coking time.



COKES FROM EQUAL WEIGHTS OF VARIOUS COALS SHOWING SWELLING GRADATION.

2. Information Derived from the Sections.

The method of preparing these sections is too recent in origin for full advantage to be taken of all that it offers. It is necessary for a large number of sections to be prepared and photographed, and for a complete set of data to be available in each case covering the nature of the parent coal or coals, the carbonizing plant, and the conditions of working, and of the properties of the coke as ascertained by the usual tests, and by tests, still to be devised, which shall serve to give reliable information as to combustibility, reactivity, and ignitibility.

Even under present conditions, a study of the sections gives a good deal of information. First, an inspection of the section as a whole shows the ash distribution, the extent of any fissures which may be present, and the general uniformity or non-uniformity of the coke. An impression is readily obtained as to the regularity of the cell structure, the orientation and size of the pores, the thickness of the cell walls, and the size and relative arrangement of the minute pores present in the cell walls. The mean size of the pores and the actual thickness of the cell walls may be measured by use of a microscope fitted with a micrometer eyepiece, and the number of cells per unit area of cross-section may be studied by employing an eyepiece fitted with a disc provided with a reticulated ruling. In cases where the nature of the coal or the thermal treatment has been unsuitable, the existence of a large area of spongy coke at the inner end of a piece of oven coke may be evident, or lack of continuity of the cell walls may indicate that the coal used has been deficient in caking qualities.

In many instances a considerable amount of information can be obtained from a polished cut section alone, without recourse to filling-up the cells by the method described; but such a section is not nearly as satisfactory a subject for the camera as is a filled-in section, and, when large numbers of cokes have to be compared, a number of photographs can be examined much more readily than can a corresponding number of lumps of coke. Further, when illustrations are required for a journal article, or for a book, the detail in a filled-in section can be reproduced almost as faithfully as it can be in the case of a line drawing, whereas, in the case of an ordinary cut section, only half-tone processes are applicable, and the fine detail is completely lost.

The accompanying photographs enable an idea to be formed as to the characteristic appearance of a filled-in section and of an ordinary cut section.

The filled-in section represents a coke which was derived from a Scotch coal carbonized in a narrow oven with a short coking period. It will be seen that the coke structure is very uniform, and that there is only a very thin band of dense coke at the cauliflower end, and a very thin band of porous coke at the inner end. Longitudinal fissures, such as would conduce to fingeriness, are absent, and there is no evidence of cross-fracture. The cell walls are thin, and contain an abundance of minute pores. The small intense black regions represent small pieces of inerts.

Pores and Cell Walls.

Though different specimens of coke have a very wide range of appearance when cut or filled-in sections are examined, the porosity does not vary between very wide limits. Malleis has given porosity figures for twenty different cokes produced in coke ovens from coals with volatile contents ranging from 17 to 41·5 p.ct., and, if one abnormal value be excluded, the range in the percentage porosity of the cokes is only between 43·8 and 58·6 p.ct.

Apparent specific gravity ranges from 0·79 to 1·09, and true specific gravity from 1·79 to 2·00 in the case of eighteen of the specimens.

In view of the small variation in porosity, it is inconceivable that porosity *per se* can have any marked effect on combustibility and kindred properties. On the other hand, with a given porosity we may have either a comparatively small number of large cells with thick walls, or myriads of minute cells with very thin walls; and the latter structure is the more desirable where combustibility and reactivity of a high order are required. A fine-grained structure may in many instances partly compensate for the adverse effects which a high true specific gravity due to over-coking has on reactivity.

The figures quoted above relate, as has been stated, to coke produced in coke-ovens—that is to say, under static conditions. In the case of continuous carbonization, apparent specific gravities as low as 0·73 have been encountered; and since the resulting coke thereby exposes a larger surface than does a coke of higher specific gravity, cokes produced by continuous carbonization under conditions in which swelling can take place much more freely than under static conditions, have a somewhat higher reactivity. On the other hand, too low a specific gravity is undesirable, since it may involve a diminution in mechanical strength.

7.—Laboratory Control of Blending.

Blending is carried out with one or more of several objects in view. For instance, a particular coal which may be available may give on carbonization a coke unsatisfactory in being too friable, or in suffering from cross-fracture or "fingeriness." In such a case addition of a strongly caking coal would improve the nature of the coke. On the other hand, the coals available may be so highly caking that a coke of much better structure and homogeneity could be obtained by carbonizing a blend containing added coke breeze or a non-caking coal. In the case of a coke-oven plant where coke is, of course, the chief product, addition of breeze or of a low-volatile steam coal would be advisable. In the case of a gas-works, where coke is a bye-product, addition of a high volatile non-caking coal would be indicated, and, thereby, use would be made of a variety of coal otherwise useless for carbonization. Even in a gas-works, coke breeze can with advantage be added to a highly-caking coal, since, though the mixture would contain a lower volatile content than that of the highly-caking coal, the daily output of gas would be increased owing to the greater speed of carbonization of the mixture, due to elimination of the plastic state.

A further possibility exists in neighbourhoods where the only coals available are non-caking, and in such an instance blending with imported highly-caking coal will enable the local deposits to be exploited. In any case, the carbonization of coals with a surplus of caking qualities is a wasteful operation, and the addition of a non-caking material is always desirable.

To enable a decision to be reached as to what blend of the raw materials available will give the best results, laboratory tests

must be carried out. A knowledge as to the swelling power and caking index of a coal gives good indication whether the coal has or has not a superabundance of caking energy. The swelling test is carried out under conditions which enable maximum swelling to occur. 1 gramme of the dry coal ground to pass 30-mesh I.M.M. is weighed into a number CO Vitreosil squat-shaped opaque silica crucible, which is then covered with its lid. The crucible is heated for 15 minutes over a full bunsen flame, and is allowed to cool. The size of the burner does not seem to affect the results to any marked degree, and one with a tube 9 mm. in bore answers very well. As regards the relative positions of the flame and the crucible, the latter should be so situated that the top of the blue cone of the flame just fails to touch the bottom of the crucible. The results obtained are very concordant, and the apparatus is simple. The accompanying diagram shows in full size the appearance of the coke masses obtained when 1 gramme samples of different types of coal are tested in the manner described, and it will be apparent that at least nine gradations are possible. By interpolation, further gradations may be made use of, so that a coal might be described as occupying position $4\frac{1}{2}$ in the swelling series; and this would denote that it coked with low medium to medium swelling.

The caking index of the coal is determined by the method described by Gray.

Very useful information is obtained by extracting the coal with benzene at high temperatures, and separation of the extracted bitumen into "liquid (oily) bitumen" and "solid bitumen" by treatment with petroleum ether as recommended by Fischer, Broche, and Strauch. These authors point out that the solid bitumen is responsible for the swelling which occurs during carbonization, but that swelling only occurs when the decomposition temperature of the solid bitumen coincides with the softening temperature of the coal, which latter depends on the content of oily bitumen. The decomposition temperature of the solid bitumen varies between 175° C. in the case of young coals to over 360° C. in the case of old coals. Caking and fusion of the coal can occur only when more than a minimum amount of oily bitumen is present. The content of oily bitumen is small in the high-volatile non-caking coals and in steam coals and anthracite, and is greatest in the caking coals.

When further work has been carried out to ascertain just how much liquid bitumen must be present for the production of a good coke, it will be possible to place the art of blending on a scientific basis. Till that has been done, it is possible only to go upon the information obtained from the swelling properties, caking index and volatile content of the coals under consideration. Thus a coal which occupies position 9 of the swelling series and has a caking index of 25 and a volatile content of 33·0 p.ct. will yield a good coke when carbonized in admixture with one-third its weight of coke breeze or with its own weight of a feebly-caking coal.

In the light of the information gained from a determination of the volatile content, caking index, and swelling properties, trial blends may be prepared in batches of 250 grammes and carbonized in a D-shaped silica muffle at 900° C. The resulting cokes are critically examined; and from their properties it is possible to decide what blends are the most suitable for large-scale working, due allowance being, of course, made for the fact that the laboratory coking test gives results better than will be realized on the plant, due to the fact that carbonization in bulk is slower than it is under laboratory conditions.

SECTION I.—COKE PRODUCTION.—(*Continued*).

Second Award, won by "J.E.B."

BY MR. MICHAEL BARASH, M.Sc.(Tech.), A.I.C., OF THE RESEARCH DEPARTMENT, WEST'S GAS IMPROVEMENT CO., LTD.

Scientific Control of Carbonization, with Particular Regard to the Agglutinating Power of Coal.

The important property exhibited by the majority of our coals, of coalescing into a solid mass when heated, has received a great deal of attention during the last century, both from the industrial as well as the purely scientific point of view. It has been stated that our national prosperity is built upon coal; it would be almost as true to say that our national prosperity is dependent upon the valuable coking properties of our coals.

According to the figures quoted by J. M. A. Mitchell, in a paper read before the Newcastle and Gateshead Gas Company Officials' Guild on Feb. 16 (see "GAS JOURNAL," March 25, 1925, p. 734), in 1922 we raised 250,000,000 tons of coal. Of this, one-third was not available for home consumption; 64,000,000 tons being exported, and about 18,000,000 tons used or sold as bunker coal. There is very little doubt that the greater portion of the exported coal was bought because of its coking properties. Of the coal consumed in this country (about 160,000,000 tons), 30,000,000 tons were carbonized in coke ovens and in gas-works, and over 40,000,000 tons were used as domestic fuel.

It is with these last two items that we must particularly concern ourselves. One has to consider the dual responsibility of conserving our national asset by carbonizing our coal under the most economical conditions, and of helping to eliminate the smoke nuisance, with its consequent danger to the public health, by introducing and advocating the more extended use of gas and coke. It is evident that, if due regard is paid to these two responsibilities, there will ensue not only an improved financial position for the gas industry as a whole, and consequently for the nation at large, but also an amelioration in conditions of the life of the individual, who constitutes the nation, and from whom the industry is recruited.

The methods of selecting the coals that will give the best and most economic results, and of deciding the proportions of coking and non-coking coals or of coking coals and coke breeze to be used in the mixtures giving such results, have developed in the past along purely empirical lines both at home and abroad. It is becoming more and more apparent, however, that not only in our own country, but in the whole of the industrial world, the control of coal resources and of the utilization of coal is being vested in chemists, or, it might be fairer to say, in scientists. Shouldered, then, with such a responsibility, the scientist should be—and, in fact, apparently is—making every effort to familiarize himself, not only with the ultimate composition of his raw material, coal, but also with the mechanism of all the changes which are brought about in the processes in which coal is utilized. Until recently little has been published of fundamental scientific interest. Within the last few years, however, there appears to have been a considerable awakening of interest, manifested by an abundance of extraordinarily useful publications on both the industrial utilization and the scientific investigation of coal.

Upon every aspect of the study of coal and its utilization sufficient has been written and published to fill many volumes; and it is considered that an attempt to review, even briefly, these publications would take up a considerable amount of useful space, and, in this instance, would not serve any very useful purpose. It has been pointed out that the first requirement of an investigator dealing with any of the properties of coal is a full and detailed knowledge of the nature and constitution of this, his raw material. Unfortunately, this knowledge is still unobtainable, and the results of a vast amount of investigation into this subject by our most eminent authorities can only be summarized by the conclusions which are arrived at in the now well-known "Monograph on the Constitution of Coal" compiled by Dr. Marie C. Stopes and Dr. R. V. Wheeler, published in 1918 by H.M. Stationery Office, and recently brought up to date and re-published by these authors (1924) in "Fuel in Science and Practice." Coal is defined as "*. . . a compact stratified mass of 'mummified' plants (which have in part suffered arrested decay to varying degrees of completeness) free from all save a very low percentage of foreign matter.*" In their summing-up of what they believe to be the best founded of modern researches, coupled with their own observations on the constitution of coal, these authors conclude that ". . . coal is a conglomerate of morphologically organized plant tissues, natural plant substances devoid of morphological organization (such, for instance, as 'resin'), together with the degradation products of a portion of the plant tissue and cell contents comminuted, morphologically disorganized, or present in the form of varying members of the ulmin group. . . . The subtlety and complexity of the substances present in coal is beyond present technique to unravel, but more can be hoped for than the first very rough separation into alpha-, beta-, and gamma-substances. Where individual tissues or identifiable parts can be isolated, the resulting products of which they are the source should be determinable. Then, fraction after fraction, the nature of each portion of the opaque coal mass may be made clear."

The main points with regard to the researches on the carbonization of coal are contained in the numerous text books and periodical publications dealing with the subject, under such headings as "Coke," "Carbonization of Coal," "Gas Manufacture," &c. The enormous volume of such data which is available is only briefly indicated in the "Short Bibliography of Coke" compiled by H. J. Hailstone, and recently published (May 27, 1925) in the "GAS JOURNAL." It will be further realized that such journals as have already been referred to here, as well as many others, including the well-known German and French publications, dealing particularly with the technology of coke, are continually adding to this valuable accumulation of knowledge.

The further one probes into this sea of knowledge, the more one realizes, however, that perhaps the fundamental property of coal, on which coke production ultimately depends, and which is the keynote in the selection of coals for obtaining the most economical results, has been neglected. This, the *agglutinating power*, may be defined as the cementing property of coal, as manifested in the production of a coherent and valuable coke on carbonizing a mixture of the coal with another coal, which (carbonized alone) would give a non-coherent coke, or with some inert material such as coke breeze, charcoal, anthracite dust, &c. It is particularly with this property of coal, for which the above claims are made, and with its numerical expression or its quantitative measurement, defined as *agglutinating value*, that it is proposed to deal in this essay on "Coke Production."

This property has been recognized and made use of in the past. Several publications have dealt with it, and attempts have been made to evolve standard and reliable methods for the determination of agglutinating value. It is considered, however, that its importance has not been sufficiently realized, and that its study and determination are of such paramount importance—particularly in the coking industry—that they should have been dealt with long ago by the highest authorities, and should rank above all other determinations of the properties of coking coals. It is proposed in this essay to describe a standardized and, it is hoped, a reliable method for the determination of the agglutinating value of coal, and to indicate the importance of this determination in the classification of coals for the production of the best grades of coke, taking also into consideration the possibility of the utilization of poorly-coking or non-coking coals and of such more or less waste products as coke breeze, anthracite dust, &c.

Coals are at present classified commercially in a number of ways varying with local usage, and founded upon the characteristic appearance, the manner of burning and nature of the coke, or the nature of the flame. These classifications are of fairly early origin. One of the earliest, and perhaps the best, of these attempts at classification on the lines of coking power and conditions of burning is the French arrangement of five classes, viz.:

1.—Poor coal, with long flame, non-coking.
2.—Gas coal, long flame, poor coke.
3.—Rich coal, shorter flame, fair coke.
4.—Coking coal, short flame, best coke.
5.—Anthracite and steam coal, little or no flame, non-coking.

The scientific classification of coals has also been attempted from as early a date as 1837, when V. Regnault ("Annales des Mines," Series 3, XII., 161-240) introduced the idea of using the ultimate analysis of the coal substance as a basis for classification. The most satisfactory and the latest of these scientific classifications is that of C. A. Seyler ("Fuel in Science and Practice," 1924, Vol. 3, 15-26, 41-49, 79-83), which in its present form, revised after his original publication in 1900-1901, is being adopted by practically all scientific investigators. It is published in the majority of modern text books

dealing with coal, and it is not considered necessary to elaborate this classification here. In none of these classifications, however, has any attempt been made to indicate how the coking properties of coal can be utilized to the best advantage—that is, to indicate, for example, how the excessive cementing properties of highly-coking coals can be made use of by blending these coals with other coals (or related materials) deficient in agglutinating properties.

An important point to be realized in connection with this work is the close co-ordination which must exist between scientific fuel researches and the technical investigations of industrial fuel problems. A critical survey of the literature, coupled with several years of purely scientific research and several years of industrial experience of carbonization processes, makes it more and more apparent that, for really valuable contributions to be made on the subject of the coking power of coals, it is essential that the results obtained in the laboratory be correlated with the results obtained on the works. In other words, industrial practice must be controlled from the laboratory, while laboratory research is practically useless unless it is coupled with industrial experience. It is satisfactory to note that the modern tendency is to realize this. The larger industrial firms concerning themselves with the utilization or treatment of coal are staffing themselves with scientifically trained men, and equipping themselves with research laboratories and plant. On the other hand, the universities and other training institutions are realizing the necessity for technical co-operation in the finishing of their products, and are making valuable efforts to provide it. It is hoped that the results and observations which are to be recorded in this paper will indicate to some appreciable extent the value of this co-ordination between scientific research and industrial problems.

We have already briefly defined what is meant by the agglutinating properties of coal. Before proceeding further with this subject, it would appear to be very desirable to define, and briefly discuss, the all-important phenomenon in the carbonization of coal with which we are concerning ourselves—namely, the coking or coalescing property of coal—in order to indicate how this is influenced by, and dependent upon, the agglutinating property.

The *coking power* of a coal may be defined as the property which that coal possesses of producing a more or less coherent coke on carbonizing it alone. The term is used industrially to classify coals broadly into two main groups—coking coals (*i.e.*, of good coking power) and non-coking coals (*i.e.*, of very poor or no coking power).

The term "coking value" should be used to signify a numerical or quantitative index of the strength of the coke produced on carbonizing a coal under certain standard conditions; the strength of the resulting coke to be determined also in some specific manner. This determination may be exemplified by the well-known method devised and adopted by G. Charpy and M. Godchot ("Comptes Rendus," 1917, Vol. 164, pp. 906-908).

Incidentally, it may be stated here that the use of the terms "caking power," "caking value," and "caking index," as synonyms respectively of "coking power," "coking value," and "agglutinating value," is to be deprecated. It is considered that the term "caking" should be applied only in such processes of segregation (such as by compression, cold cementation, baking, &c.) which do not involve the common processes of carbonization; and it should not be used at all in the coking industry and in the literature dealing with coking processes.

The importance of the study of the agglutinating property will be indicated and fully discussed after the following outlines of researches which have been carried out by the author in this connection are described. It will be observed that this property has a distinct bearing on all the subjects (with the exception of "methods of quenching") which are suggested for treatment in the essay on "Coke Production" (Section I.) on p. 402, col. 2, of the Feb. 18, 1925, issue of the "Gas Journal." It may serve a useful purpose to enumerate these subjects here for reference:

1.—The quality of coals carbonized.
2.—The sizes of coal carbonized.
3.—Methods of carbonization.
4.—The temperature at which carbonization shall take place, having regard to the characteristics of the coal.
5.—Blending of coals, and the blending of coal and coke.
6.—Methods of quenching.

With regard to the constituents of the coal mass which are responsible for the coking and agglutinating properties of coal, sufficient reference has already been made to these in the literature, and it is hoped to deal further with this and with allied subjects—such as the mechanism of the coking process and the theory of coking—in several communications in the near future.*

* Note.—The subject matter from which the material for this essay is drawn has accrued from a scientific investigation of the agglutinating property of coal which was commenced in 1919, and has been followed up by several years of industrial experience, resulting from the unique opportunity of carrying out prolonged tests and observations on about a dozen modern gas-works, large and small, in Great Britain and Ireland. In the experimental work to be described here, it is proposed to give only summarized extracts of the work actually carried out. Further details and the methods of procedure will be elaborated in subsequent publications.

Determination of Agglutinating Value.

It will be obvious that the first essential factor in the study of the agglutinating property of coal, both for scientific and industrial purposes, is the adoption of a standardized, reliable method for the determination and comparison of the agglutinating values of different coals and coal constituents. Since 1870, when Dr. Richters ("Dingler's Polytechnischer Journal," 1870, Vol. 195, p. 71) first proposed a tentative method for this determination, suggesting the admixture of varying proportions of finely-divided quartz with 1 gramme of coal, to determine the ratio of inert matter to coal when the coherence of the "coke" is just destroyed by testing lightly with a 500 gramme weight, at least eighteen varieties of this method have been put forward, each claiming superiority over its predecessors. Each of these methods has been subjected to more or less serious and adverse criticism in the literature, and none has been authoritatively proposed for adoption in the classification of coals for carbonizing purposes.

As the result of a critical survey of these methods, coupled with personal experimental and industrial investigation, the following method has been devised, in which an attempt has been made to render all the details of the determination easily standardizable and devoid of complications which could militate against their adoption both for scientific research and industrial application. In developing this method, four coals used for the research were selected as typical representatives of the Lancashire coalfield—Arley, Mountain Mine, Yard (Bickershaw), and Ravine (Abram). A description of these coals, of their industrial applications, and their analyses, is given in Appendix I. to this paper. The method has subsequently been applied to the examination of a variety of coals from many districts, and has proved its universal reliability in the classification of coals for industrial purposes, particularly from the point of view of gas-works practice.

The coal sample is ground (by degrees) to pass completely through a 90-mesh ("I.M.M.") sieve with the production of as little very fine powder as possible. The inert material, electrode carbon (see Sinnatt and Grounds, "Jour. Soc. Chem. Ind.," 1920, Vol. 39, p. 83 T., or "Bull. 8, Lancashire and Cheshire Coal Research Association"), is ground to pass through a 60-mesh ("I.M.M.") sieve, and the portion is retained which remains on a 90-mesh sieve.* Quantities of coal and 60-90 electrode carbon are weighed out so as to give a total of 2 grammes (or slightly more) of mixture. They are thoroughly mixed, and two 1-gramme lots of the uniform mixture are weighed into separate silica tubes, approximately 2 in. long by ½ in. diameter (internally). The two tubes and contents are treated in exactly the same way, and serve as duplicates for checking the uniformity of the mixture.

Each tube with its contents is heated for exactly five minutes at 800° C. in an electrically-heated (platinum wound) silica furnace. A small silica crucible with its curved under-surface resting on the rim of the tube acts as a lid, and also rests on top of the silica furnace, so that the tube and contents are completely immersed in the heating apparatus at a constant temperature.† The tube is transferred, for cooling, to a desiccator (being kept throughout in a vertical position), and then carefully inverted, and the coked residue allowed to slide out on to a polished metal scoop. The proportion of powder is noted, and the coherent mass (if any) is tested for comparative crushing strength with the fingers. This procedure is repeated with mixtures containing varying proportions of electrode carbon until the minimum ratio of the latter to coal, which gives a non-coherent powder, is ascertained. The agglutinating value is then stated as the proportion of coal to electrode carbon ($1 : x$) in this mixture.

It is advisable that this determination should be preceded by a determination of the volatile matter evolved from the coal alone at 800° C. (in the same apparatus and by the method to be described), so that the coke from this latter determination should be available for examination of the coking properties, and for the indication which it furnishes as to whether the coal will have a high or a low agglutinating value. Immediately after the tube has been removed from the furnace, and the degree of swelling of the coke ascertained, the weighing-out and preparation of the mixtures can be commenced. It has been found that these processes and the carbonizations can be so fitted-in that, particularly when two or more samples are being tested at the same time, the total time taken for each sample, to determine the percentage of volatile matter and the agglutinating value, and to obtain a good general indication of the coking propensities of the coal, may be reduced to approximately one hour.

The agglutinating values obtained for the four coals (at 800° C.) by the above method of determination are:

Arley	1 : 7
Mountain Mine	1 : 13
Bickershaw Yard	1 : 10
Abram Ravine	1 : 8

* Note.—The importance of using sieves of standard mesh has been stressed in several publications. For this determination the accurate grading of the electrode carbon is absolutely essential, and the standard Institute of Mining and Metallurgy sieves have been adopted. The use of other sieves gives rise to considerable variation in results.

† A more detailed description and illustrations of the special furnace devised for this work will be found in Appendix II. to this paper.

It has proved extremely satisfactory to note, in subsequent repetitions of these determinations, using the same samples of coal and the same method but different samples of the inert material, electrode carbon, that identical results were obtained. The significance of these values will only be briefly referred to at this point.

Arley, with an agglutinating value of 1:7, is recognized as an ideal gas-making coal from the point of view of yield of volatile products, the quality of its coke, and particularly its ease of working under practically all carbonizing conditions. Its valuable properties confer upon it the reputation of being a standard coal against which to compare other coals, and which is often used for comparisons of different carbonizing systems. These facts are supported by the results which have been published with regard to Arley by the Fuel Research Board, the Lancashire and Cheshire Coal Research Association, and several individual investigators.

Mountain Mine, on the other hand, with an agglutinating value of 1:13, although under certain conditions (in coke ovens, for example) yielding an excellent metallurgical coke, proves difficult to carbonize alone in ordinary gas-works systems. Under these conditions, it has the reputation of being a "sticky," swelling coal, and yields a rather friable coke. Its high agglutinating value shows that it contains an excessive amount of agglutinant, and this valuable property is being wasted if the coal is not blended with a poorly coking or non-coking coal or with coke breeze.

Ravine resembles Arley in its properties, as it does in its agglutinating value.

Yard coal, with its agglutinating value intermediate between those of Arley and Mountain Mine, is found, as would now be expected, to have intermediate coking qualities. Though not quite as troublesome as Mountain Mine, it is not nearly so easy to deal with as Arley.

Before proceeding with the elaboration of this theme, it is considered necessary to describe several further closely-related investigations on these coals, which have a definite bearing on the study of the coking properties of coals as influenced by their agglutinating values.

Percentage of Volatile Matter and Type of Coke Produced from Coal at Different Temperatures.

The modified furnace (described in Appendix II.) which was used in determinations of agglutinating value was found to be specially suitable for the determination of volatile matter, and to give valuable information regarding the relative coking properties of coals. Particularly interesting observations were made with regard to the swelling of coals during carbonization as evinced by the size of the coke cylinders produced. Determinations were carried out on the four coals at temperatures between 400° C. and 900° C., and the yields of volatile matter, calculated to ash and moisture-free basis, plotted against the temperature of determination, are represented graphically in fig. 1. The values obtained by the standard American method are interpolated on to these curves, and the temperatures thus obtained would indicate that there may be a variation by this method equivalent to about 100° C. (832° to 927° C.) in the conditions of this determination. This variation in the results obtained by the crucible method can only be accounted for by the assumption, which has been made by several other investigators, that atmospheric oxidation has a vitiating effect on the results obtained under these conditions.

A summary of the results obtained (including those by the American method) is given in Table I., and the values, calculated from these results, for use in the curves (fig. 1), are given in Table II. Each of the determinations was carried out in duplicate, and such results have been found to agree invariably, by the method described, to within 0·1 p.ct. of volatile matter.*

Table I.—*Summary of Volatile Matter Results.*

Coal.	Temperature (° C.)						American Method.
	900.	800.	700.	600.	500.	400.	
Arley	36·96	34·48	32·75	29·76	24·47	20·65	36·85
Mountain Mine .	29·36	27·33	22·76	21·24	18·40	16·74	28·48
Bickershaw Yard	40·55	38·25	36·05	33·43	29·28	18 84	41·08
Abram Ravine .	35·77	32·35	31·05	28·21	24·48	15·45	36·42

Table II.—*Above Results Calculated to Ash and Moisture-Free Basis (i e, Volatile Organic Matter from Organic Coal Substance.)*

Coal.	Temperature (° C.)						American Method.
	900.	800.	700.	600.	500.	400.	
Arley	36·51	33·94	32·14	29·03	23·54	19·58	36·40
Mountain Mine .	32·66	30·23	25·02	23·28	20·04	18·15	31·54
Bickershaw Yard	42·24	39 66	37·25	34·35	29·76	18·22	42·81
Abram Ravine .	35·43	31 83	30·46	27·47	23·55	14·05	36·11

* Note.—The cokes produced from all these determinations, in duplicate, were mounted on white cards, and photographed. Reproductions of these, and full details of the determinations, will be published in the near future. They are not included here, in order to avoid making this paper too voluminous. The sizes of the coke cylinders were carefully noted, and their significance will be discussed collectively with the results of the investigations to be dealt with further.

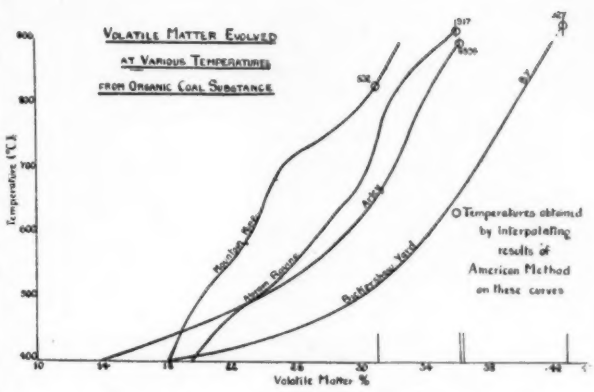


Fig. 1.

Effect of the Addition of Inert Matter to Coal during Carbonization.

This subject has been dealt with in a Special Bulletin (No. 3, Lancashire and Cheshire Coal Research Association) by Sinnatt and Grounds; and it is stated that the percentage of volatile matter may be considerably increased—an increase of 43 p.ct. is recorded in the case of one coal—by the addition of varying proportions of electrode carbon (or other inert materials) to the coal before carbonization. This observation would have such an important bearing, both on the determination of agglutinating value and on industrial practice, that it was considered essential to repeat the investigation in order to verify these results.

Determinations of volatile matter were therefore carried out on the four coals, in the apparatus which has been described, using varying proportions of coal to electrode carbon from 1:1 to 1:20. The volatile matter was then calculated as a percentage of the amount of coal used in each mixture, allowance being made for 1·18 p.ct. of volatile matter evolved by the electrode carbon at 800° C. The results obtained were in close agreement for the four coals; a typical selection of those obtained with the Arley coal being as follows:

Table III.

Ratio of Coal to Electrode Carbon.	Volatile Matter, P.Ct. of Coal.
1 : 0	34·48
1 : 1	35·08
1 : 4	32·60
1 : 6	33·53
1 : 11	33·36

It will thus be observed that the claim made by Sinnatt and Grounds is not substantiated. Recently, Webster and Wiggington ("Fuel in Science and Practice," 1924, Vol. 3, pp. 142-144) also undertook the repetition of this investigation, and also failed to obtain any indication of such an increased yield of volatile matter. These authors attribute the results obtained by Sinnatt and Grounds to oxidation of the charge in the platinum crucible during the last five minutes of heating in the American test. Judging from the flame, the volatile matter is evolved in this test during only the first two minutes of heating. Sinnatt and Grounds do not offer any explanation for the phenomenal results they obtained.

My own results show that in practically all the mixtures there is actually a slight decrease in the evolution of volatile matter by the coal—probably due to the absorption and fixation of some of the tarry products in the pores of the preponderating inert matter. In the case of the 1:1 mixtures, however, there was a distinct increase in volatile matter, averaging about 3 p.ct. This increase is, no doubt, due to two causes—namely:

(*a*) The increased conductivity of the mixture, owing to the presence of electrode carbon. This, like other artificially prepared carbons (including coke breeze), is certainly a much better heat conductor than coal.

(*b*) The greater porosity of the mass, owing to the reduction of plasticity, and to the porous nature of the inert matter introduced into the mixture.

It is evident that these observations are quite important from the industrial point of view.

Effect of Temperature on Agglutinating Value.

Primarily, the determinations of agglutinating value at different temperatures were carried out in order to determine which was the most suitable and convenient temperature to adopt for regular use. A consideration of the results obtained, taken in conjunction with those referred to previously, established several remarkable facts in the correlation of agglutinating and coking properties.

Results were obtained with the four coals at temperatures

between 500° and 900° C. These are summarized in Table IV., and represented graphically by the curves in fig. 2.

TABLE IV.—*Summary of Results.*

Temperature of Determination.	Agglutinating Values.			
	Arley.	Mountain Mine.	Bickershaw Yard.	Abram Ravine.
900° C.	1 : 6	1 : 12	1 : 10	1 : 7
800	1 : 7	1 : 13	1 : 10	1 : 8
700	1 : 6	1 : 11	1 : 9	1 : 7
600	1 : 5	1 : 9	1 : 8	1 : 6
500	1 : 4	1 : 6	1 : 6	1 : 5

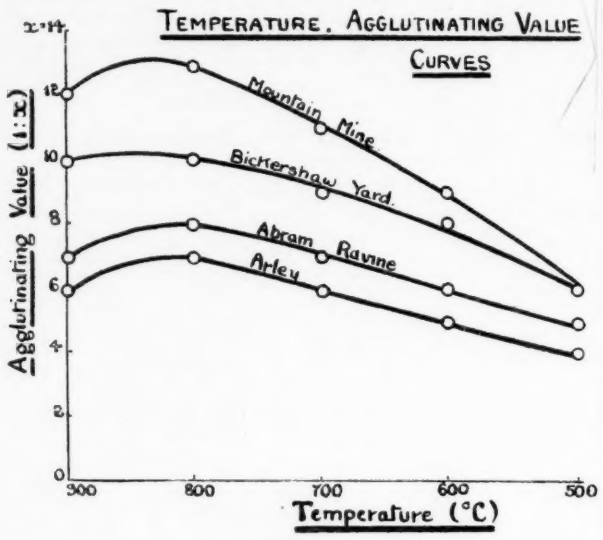


Fig. 2.

Several fundamental facts (as enumerated below) concerning the carbonization of coals may now be established from a consideration and correlation of the results of the investigations which have been summarized up to the present.

(1.) First, corroboration is obtained of the claims which have been made by several investigators that the addition of coke breeze (in limited proportions) to highly coking coal before carbonization confers marked improvement, not only on the yield of volatile products and the quality of the resulting coke, but also in the ease of manipulation of the coking process. At the same time, the fact must not be overlooked that this procedure helps to eliminate the necessity for the removal or disposal of what may be looked upon as a troublesome waste product—coke breeze. In this connection particular interest attaches to a patent taken out by Souquière as early as 1895 (British Patent No. 1091, 1895), claiming "A New and Improved Process for Distilling Coal," which contains the following:

> The coke produced by any of the known processes is pulverized and mixed with various proportions of pounded coal of the same or different kind as that from which the coke has been produced. The mixture is then heated, either in the distilling apparatus used for making the coke originally or in a separate apparatus, and thus new coke is obtained composed of one part coke twice distilled, and another part which has been only once distilled; the coke twice distilled being always of greater density than that only once treated. Further, this improved coke does not present a spongy appearance; it is sonorous and firm and suitable for all purposes, hence its commercial value is incontestably superior to that of coke prepared by known processes. Moreover, the coking operation is effected more rapidly, and as the contents of the retort diminish in volume the coke produced may be easily withdrawn and in a single lump.

The importance of the above observations (or claims) is obvious, in spite of the fact that it is extremely unlikely that one would nowadays adopt the proposed measure of pulverizing the coke for making the mixture, in view of the fact that coke breeze is available almost universally for the purpose.

In a recent paper, J. Roberts ("Trans. Inst. Min. Eng.," 1921, Vol. 42, p. 12), dealing with the "Low-Temperature Carbonization of Coal," confirms the claims of Souquière, and adds the following interesting comments on the subject:

> Coke breeze was for many years a worthless product, and it is, therefore, unfortunate for low-temperature pioneers that advantage was not taken of this remedy for swelling of coals at a time when breeze was wasted as ballast, &c.
>
> High-temperature coke or "Coalite" breeze may be used for this purpose in suitable proportions that must be determined by laboratory tests for any given coal.

It is satisfactory to note the emphasis in this suggestion of the laboratory control of the process.

Reference is also made in the above paper to a process patented by this author (E.P. No. 187,336) for mixing coking coals with non-coking coals containing 20-45 p.ct. of volatile matter—

> in such proportion that the non-coking coal utilizes the excess of binding material in the coking coal during carbonization, thus preventing expansion and securing a product with a bright and hard outer laver.

In the discussion of Roberts' paper, L. Silver gives an interesting comparison of coke with a cement-concrete. He suggests that the decomposition product of the "binder" forms the cement connecting the particles of the infusible constituents of the coal, and that a coal with "surplus binder" is one in which this cement is more than sufficient to fill the interstitial space between the particles. He recognizes also the important difference which exists between the agglutinating value and the coking value of a coal, in that he states that the "coking index" (referring to the agglutinating value) of a coal is no criterion of the hardness or density of the carbonization product, though it provides a measure of the amount of excess binder in the coal.

This view of the constitution of coke affords a means of accounting for the formation, from a mixture of coal and coke breeze, of a product which is stronger than that from the coal, and also stronger than the coke from which the breeze was obtained. With the optimum mixture of coal and coke, the binder should be just sufficient to fill the interspace between the inert (infusible) particles when these are in contact. In this case, crushing would be resisted, not only by the strength of the cementing medium, but also by the friction between the particles themselves. Since the coke from which the breeze was formed gave way on crushing at the weakest parts of the mass, the average strength of the unbroken particles must be higher than that of the original mass. If these conclusions are correct, the strength of the product should increase to a maximum, and then decrease rapidly with increasing proportions of breeze. Silver states that he actually found this to be the case in crushing tests on prepared samples of such cokes; and the results obtained in the investigations which have been referred to in this paper confirm these observations.

Finally, as indicating the latest word on this subject, Dr. Geoffrey Weyman, in his address to the recent Auxiliary Meeting (May 23, 1925) of the North of England Gas Managers' Association, urged, in view of recent investigations, the consideration of the inclusion of blending plant on gas-works for properly mixing charges with coke breeze or other non-coking material. An editorial comment on this statement ("Gas Journal," June 3, 1925) agrees that ". . . there is much to be done in this way with the dual object of improving heat transmission through retort charges and enhancing the physical characteristics of coke."

(2.) A consideration of the results obtained in the determinations of yield of volatile matter at different temperatures (Tables I. and II., and fig. 1) shows that, for any given coal, a given evolution of volatile matter corresponds to a given temperature. Carbonization, therefore, constitutes a sort of fractional distillation of coal, and one can only attach to the yield of volatile matter a relative value depending upon the method, and particularly the temperature adopted. Further work has shown that prolonged heating (even up to eight hours, in the experimental work discussed) does not increase the yield of volatile products. In other words, to each temperature for each coal there corresponds a fixed yield of volatile matter which is unchanged by prolonged heating.

Burgess and Wheeler ("Trans. Chem. Soc.," 1910, Vol. 97, pp. 1917-1935) investigated the composition of the products evolved from coal at different temperatures, and concluded that a "critical period" in the decomposition appears to lie within the range 700° to 800° C. All the hydrocarbons of the paraffin series, and the richer products of carbonization, are evolved below this point. Further heating results mainly in the production of hydrogen and methane from the decomposition of what may be termed the "coke molecule." At the highest temperatures attained in laboratory investigations (1100° C. to 1200° C.), there is no indication of a limiting point being reached in the evolution of gases from coke. It is evident that, for such an end point to be reached, a temperature would have to be used considerably above those which are conveniently attainable in most industrial and research laboratories. It has been found that 800° C., which is well within the scope of most investigators, is a very convenient temperature for prolonged use in the electric furnace which has been mentioned. It is a fair mean of the temperatures adopted by other authors, and, above all, it gives results which agree very well with those obtained industrially by the carbonization of coal in continuous vertical retorts (with a minimum or absence of steaming) at chamber temperatures of 1200° to 1300° C.

It is therefore suggested that 800° C. would be a suitable temperature to be adopted for the general determination of "volatile matter" in coal, and that these conditions would give the best indications of the relative values of coals from this point of view. The reasons which have been given here are,

among several others, those which influenced the choice of this temperature in the investigations which are under review.

(3.) A comparison of the results which have been given indicates that the percentage of volatile matter evolved from different coals under the same conditions bears no relation to the agglutinating values of these coals. While this generalization is true, however, as between different coals, if one considers individual coals a definite relationship is found to exist between the two determinations as the temperature varies between 500° and 800° C. Within these limits, the agglutinating value and the yield of volatile matter appear to increase regularly with each increment of temperature. Above 800° C., however, while the volatile matter increases, the agglutinating value does not show the same tendency.

(4.) Examination of the agglutinating value curves (fig. 1) shows that 800° C. appears to be a critical point in the agglutinating values of the coals under investigation. These values in all cases (as has been stated above) increase regularly with increase of temperature, until a maximum value is reached at 800° C. At higher temperatures, the values obtained are generally lower than those at the critical temperature.

This observation is worthy of careful consideration in the industrial carbonization of coal. It would appear that, where a high yield of volatile or gaseous products is the main objective, the highest temperatures should be aimed for; whereas if the quality of the coke is the chief consideration, it would be preferable to carbonize at more moderate temperatures. In cases, however, where only such coals are available which contain excessive agglutinating properties, and coke breeze or coals of very poor coking properties are not readily obtainable for blending, the use of the higher temperatures is essential. In such cases, by the reduction of agglutinating property, the double advantage is obtained of producing a good quality coke and a high yield of volatile products.

These observations have been borne out in numerous instances in actual industrial experience, particularly in the cases of highly agglutinating Durham and Somerset coals.

(5.) Finally, important observations have been made with regard to the relation between the swelling properties and the agglutinating value of coals. The cokes resulting from the determinations of volatile matter on the four coals at the stated temperatures were carefully examined, and the degree of swelling in each case computed (or measured by displacement in doubtful cases), and noted as a percentage of the volume occupied by the original coal. It was found that this value bears a distinct relation to, and gives an indication of, the agglutinating value of the coal. This is not only true for different coals carbonized under the same conditions, but is also found to be the case with any individual coal when the determinations are carried out at varying temperatures.

Thus, the results show that the agglutinating values of the four coals under standard conditions (at 800° C.) are in the order (highest to lowest): Mountain Mine, Yard, Ravine, Arley; and the degree of swelling of the cokes produced at the same temperature follows essentially the same order. Mountain Mine gives the most voluminous coke, Arley the least; and the Yard and Ravine form cokes of intermediate size.

In studying the individual coals it was found that, as in the case of the agglutinating value determinations, a critical point was reached at 800° C. Up to 800° C. the coke cylinders increased in size, while at 900° C. a distinct reduction in swelling was obtained. It is thus evident that these two properties (swelling and agglutination) are interdependent, or that both are determined by the same phenomena during the process of carbonization. The experimental determination of the degree of swelling of a coal, by the method which has been outlined, thus affords a valuable guide to the treatment (blending, &c.) to which the coal should be subjected previous to its industrial carbonization. On the other hand, the determination of agglutinating value furnishes valuable information regarding the probable behaviour of the coal in existing carbonizing systems.

It is thus, by the study of these properties in the laboratory, that means are afforded for the classification of coals for carbonizing purposes and for the selection of the most suitable types of coal to be used in this industry. By the elaboration of this study, as will be further indicated, valuable information is obtained with regard to the utilization, in the most economic manner, of coals with excessive agglutinating properties and of coals which are at present recognized as being of poor or non-coking quality. In this connection it must be pointed out that the available supplies of coals of high agglutinating value—that is, the most valuable coals for carbonization purposes—are being rapidly exhausted, notably in Lancashire. Large stocks are available of poor coking coals, non-coking slacks, and coke breeze. It is in the interests of national economy, and for the unquestionable benefit of the gas industry, that the highly-agglutinating coals should be conserved and the cheaper varieties utilized to the greatest possible extent.

Before proceeding to the final summing-up, the results of several further investigations in this series will be briefly outlined. It is considered that they not only relate to the points which have been discussed, but have an important bearing on the storage and treatment of coal prior to its use for coke production.

Effect of Heating Coal at Low Temperatures (500° C. and Below) Prior to Carbonization.

Samples of the coals were heated in the apparatus which has been referred to, at temperatures of 500° C., 400° C., and 300° C., and in an air oven at 200° C. and 105° C. (the temperature adopted for "moisture" determinations), and the resulting products examined, from the point of view of yield of volatile matter and quality and quantity of coke, after periods varying from a quarter-of-an-hour to eight hours. In all cases this pre-heating reduced the swelling of the coals on subsequent carbonization, and also materially reduced the coherence of the resulting cokes. Another interesting observation in this connection was that after such a pre-heating (for short or long periods) and subsequent carbonization at 800° C. under the standard conditions which have been described, there was invariably an increased coke yield. In other words, extra carbon was "fixed" in the coke at the expense of volatile products. This process, whereby the fixed carbon content is increased, may be compared with the natural process of "anthracitization," and is probably an actual artificial reproduction of this natural phenomenon.

The observations recorded in this section are of importance in connection with processes such as that claimed by Illingworth (E.P. No. 164,104, May 30, 1921) for "Improvements in the Coking of Coals," of which the following is an abstract:

> Thus by regulated pre-heating of coal, which if treated by ordinary processes would produce a porous coke, it is possible to obtain a dense, hard coke, the degree of hardness and porosity being determined by the duration of the preliminary heating and the temperature at which it is conducted.

Effect of Treating Coal with Pyridine and Chloroform. Agglutinating Values of Coal Constituents Separated by these "Solvents."

In view of the statements which have been made by several investigators regarding the constituents of coal which are responsible for the agglutinating and coking properties, an investigation was carried out to determine (*a*) the effect produced on the coal during its treatment with so-called "solvents" which are employed in resolving it into its constituents, and (*b*) the extent to which each of these constituents contributes towards the agglutinating properties of the coal.

The coals were boiled for consecutive periods with pyridine and (fresh samples) with chloroform, according to the methods employed in their extraction. The solvents were then removed (by evaporation and washing), without separation of the soluble and insoluble portions, and the residues so obtained were examined. It was found that the swelling properties of the coals were rapidly destroyed by the treatment, and the effect on the agglutinating value is indicated clearly by the following typical curves (fig. 3) obtained with Mountain Mine coal.

These results are particularly noteworthy in view of the fact that none of the agglutinant has been removed from the coal during the treatment.

Fresh samples of coal were separated according to the usual methods described in the literature, into alpha-compounds (insoluble in pyridine and chloroform), beta-compounds (soluble in pyridine, insoluble in choloroform), and gamma-compounds (soluble in pyridine and in chloroform). The properties and agglutinating values of the products so obtained are summarized as follows:

Table V.—*Properties of Alpha-, Beta-, and Gamma-Compounds.*

—	Yield.	V.O.M.	Swelling.	Aggregate Value.
	P.Ct.	P.Ct.	P.Ct.	
Arley—				
Original coal	..	32·66	100	1 : 7
Alpha-compounds	82·40	30·09	−10	1 : 1
Beta- ,,	12·75	35·60	300	1 : 6
Gamma- ,,	7·78	80·50	..	1 : 55
(Beta + gamma)	19·30	48·90	900	1 : 23
Mountain Mine—				
Original coal	..	26·50	400	1 : 13
Alpha-compounds	80·60	23·08	−10	1 : 1
Beta- ,,	13·52	29·60	600	1 : 11
Gamma- ,,	7·49	70·80	..	1 : 65
(Beta + gamma)	20·46	39·80	2500	1 : 50

In the above table, V.O.M. is an abbreviation for volatile organic matter at 800° C. "Beta + Gamma" is the portion of coal soluble in pyridine not separated by chloroform into beta and gamma).

The swelling of the gamma-compounds is not given above, as this class of compounds does not form a "coke," but a thin, brittle skin inside the tube.

The really important observations made during the above investigations are as follows:

Re-mixing of the alpha-, beta-, and gamma-compounds in the proportions in which they were originally present in the coal does not reproduce a mixture having the same properties as the coal, but one with a considerably lower agglutinating value, and devoid of swelling properties. Furthermore, the low agglutinating residues from the treatment of the coals with pyridine or chloroform (as fig. 3) are found on extraction to

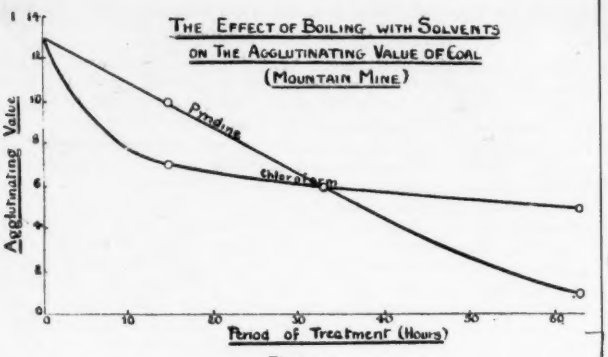

The Effect of Boiling with Solvents on the Agglutinating Value of Coal (Mountain Mine)
Agglutinating Value
Pyridine
Chlorobenzene
Period of Treatment (Hours)

Fig. 3.

yield as much agglutinant (both beta- and gamma-compounds) as the original coals.

Analysing these observations one must come to the conclusion that the manifestation of agglutination is not totally due to the agglutinant, but is influenced to a marked degree by the condition (porosity, &c.) of the non-agglutinant (or inert material) present in the coal. In other words, a coal may contain a considerable amount of agglutinant, but may behave as a poor coking coal, owing to the influence of the inert material with which this agglutinant is co-mingled in the mass.

This is important, in view of the fact (as will be mentioned later) that such coal may be considerably improved by the admixture of a fusible or liquid material, not necessarily an agglutinant, which will to some extent satiate the porosity of the inert material present, and so leave a larger proportion of the inherent agglutinant available for binding together the infusible particles.

Agglutinating Values of the Banded Constituents.

Two samples of coal, "A" and "B," chosen for this work because they contained appreciable quantities of all four of the Stopes banded constituents, vitrain, clarain, durain, and fusain (Dr. Marie C. Stopes, "Proc. Roy. Soc.," 1919, (B) 90, p. 470), were carefully separated into these constituents, and agglutinating value determinations gave the following results:

Agglutinating Values.

	Coal "A."	Coal "B."
Original coal	1 : 15	1 : 4
Vitrain	1 : 9	1 : 3
Clarain	1 : 17	1 : 7
Durain	1 : 6	1 : 5
Fusain	Absolutely non-coking	

Coal A resembles Mountain Mine in properties; used without blending or special care, it is troublesome in continuous vertical retorts, and produces a friable coke. Coal B contracts on carbonization, works very easily, but also gives an inferior soft coke.

It will be observed that these banded constituents vary remarkably in their agglutinating values, and each will therefore give rise to a different type of coke. Several investigators have remarked upon the non-uniformity of the cokes produced from banded coals. Particularly is this the case with coals which contain appreciable proportions of fusain. The latter being absolutely non-coking (practically devoid of beta- and gamma-compounds) forms distinct lines of weakness in the coke, and so contributes largely to the production of breeze.

From the point of view of industrial carbonization, this investigation, therefore, indicates the importance of intimately mixing the coal. This can only be brought about by reducing the coal first to a fairly fine state of sub-division, although by this one does not contemplate pulverization to a fine powder, but sufficient reduction of lumps to ensure an intimate and uniform mixture, particularly where blending is being carried out. In this connection an investigation of the influence of fineness of both the coal and the inert matter in the determination of agglutinating values, gives results which should prove useful when translated into the industrial technique of the production of coke by the blending of coal with coke breeze.

In the laboratory determinations it was found that, if the coal particles were coarse (above 60 mesh), irregular and non-uniform segregations of particles of electrode carbon (60-90 mesh) resulted from the coked mixture. When the coal was ground to pass through a 90-mesh sieve, a uniform product was obtained; grinding the coal still further did not result in any additional improvement. Using the "through 90" coal, it was found that particles of electrode carbon above 60 mesh again resulted in a non-uniform product; 60-90 mesh gave the desired uniformity; but when the inert matter was finer than 90 mesh the agglutinating value was considerably reduced, and very weak cokes resulted. This latter effect is, no doubt, due to the cementing material being spread over the very large area comprised in the innumerable surfaces of the finely-ground electrode carbon.

These observations lead to the conclusion that, in order to obtain a uniform coke industrially by the blending of highly-coking coals with coke breeze, it is advisable to pulverize the coal so that the particles are, on an average, somewhat smaller than the average size of the particles of breeze.

Effect of Weathering and Treatment of Coal with Chemical Reagents.

It is rather difficult to give, in a short account, an interpretation of the mass of numerical data which has accrued from this investigation. Coals were "weathered" by exposure to atmospheric conditions, soaking in water, aeration in water, and boiling in water, for varying periods. The effect of treating coal with strong and weak oxidizing and reducing agents and with strong and weak, hot and cold, aqueous solutions of acids and alkalis, was systematically investigated. In all cases the tendency was to reduce the swelling power of the coals and to diminish the agglutinating value. In some cases, as would be expected, the effect produced was exceedingly rapid (*e.g.*, in an atmosphere of chlorine a strongly agglutinating coal like Mountain Mine becomes absolutely non-coking in five minutes), while in other cases the effect is only gradual, extending over fairly long periods.

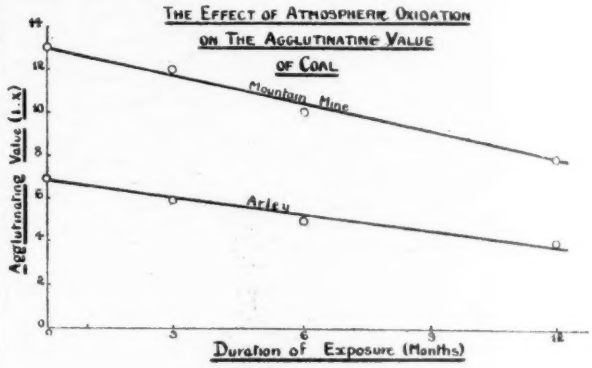

The Effect of Atmospheric Oxidation on the Agglutinating Value of Coal
Agglutinating Value (L.K.)
Mountain Mine
Arley
Duration of Exposure (Months)

Fig. 4.

Fig. 4 shows the effect of atmospheric oxidation on the agglutinating values of Arley and Mountain Mine coals.

Instances of the deleterious effect produced in stacks of coal are fairly common, and several cases can be quoted where the coking properties of coals have deteriorated considerably owing to insufficient care being taken in storage. Such effects may be enhanced by storing coals without due protection from atmospheric conditions; and the proximity of coal to engine exhausts or possible contamination with acid and other industrial fumes and liquids should be avoided where possible, if the coal is to be used for coke production. It is worthy of note that several of the products from the above investigations, in which the coking properties had been practically (or completely) destroyed, were found on extraction with pyridine to have had their agglutinating constituents unimpaired by these treatments.

As has been previously mentioned, it appears that the non-agglutinating, infusible constituents of the coal are readily attacked, and are so altered that their avidity for the cementing material is considerably enhanced during carbonization. A simple visualization of this conversion may be made by striking an analogy between the two forms of this inert material and the two forms of calcium carbonate occurring in nature—*i.e.*, marble and limestone. A unit quantity of marble particles would require a certain amount of fluid cementing material to bind them into a coherent mass. Convert these particles into particles of limestone, of a porous nature, and it is evident that, to obtain the same coherence, considerably more agglutinant would be necessary; the agglutinant being not only utilized in cementing the particles together, but being drawn by capillarity into the pores of each particle.

Increasing the Agglutinating Power of Coals.

In the final investigation of this series, a study was made of possible methods of increasing the agglutinating value of coals, particularly with a view to discovering whether non-coking coals could be converted into coking coals. This investigation was carried out from the following three points of view:

(*a*) The addition of agglutinating materials.
(*b*) The addition of materials (other than agglutinants) which would lower the viscosity of the molten coal during carbonization.
(*c*) The effect of mixing coals or coal components of different agglutinating values.

The conclusions arrived at in the correlation of agglutinating power and the viscosity of molten coal during carbonization (as evinced by the degree of swelling) indicate that the agglutinating value of a coal can be increased by decreasing the viscosity (or increasing the fluidity) of the coal during the period when it is in the molten condition.

As has already been indicated, a coal may be non-coking because of a deficiency of agglutinant or because the inherent agglutinant is absorbed to a large extent by the infusible

materials present in the coal conglomerate. In the former case, agglutinant must be added to the coal. In the latter case, any diluent material, fluid under the conditions of carbonization, may be effective in increasing the amount of agglutinant available for cementing the mass into a coherent coke. A review of the literature will show that a large number of materials and processes have been patented recently to satisfy both these conditions. Pitch and tar have been used for many years, and in many different ways, as agglutinants, for increasing the coking power of coal. More recently, several vegetable waste products, preparations from sea-weed, cassava starch, and asphaltic products, are among the materials which have been proposed as substitutes for pitch in this respect. Among recognized non-agglutinants, suggestions have been made for the use of anthracene oil, creosote oil, mazout (or mazut), petroleum, and various aqueous emulsions and suspensions of oils; and it is claimed usually that these oils function as required during carbonization, but are almost completely recovered in the volatile products collected from the processes.

In this connection, it is interesting to quote the following observations from a recent German source (F. Lierg, "Zeit. angew. Chem." 1922, Vol. 35, pp. 264-268, German Patent No. 362,362, 16/3/19):

> Non-coking coal ("sinter coal") requires 20-30 p.ct. of pitch admixed to make a good coke; but if the pitch is dissolved in tar oil, 7-8 p.ct. suffices. . . . The residue from the pyridine extraction of a coking coal had lost its coking properties, and re-addition of the extract (which was highly coking) did not restore them; but when the extract was dissolved in a solvent and added, the coking property was restored.

In the course of the investigation under review, results were obtained which confirmed the above observations. For example, admixture of 2 p.ct. of paraffin wax or 5 p.ct. of anthracene oil was found to double the agglutinating values of the Arley and Mountain Mine coals.

A mixture of coals of different agglutinating values gives the expected average value of the individual coals. An important observation in this respect, however, was that the swelling power of the mixture is always considerably lower than what would be computed from the swelling of the components. This indicates that the industrial blending of suitably chosen coals would give rise to cokes of any desired density and uniformity as pre-determined by laboratory assay. These conclusions do not hold, however, when applied to the blending of agglutinating coals with coals or other materials totally devoid of agglutinating properties. In many cases which were investigated the latter class of materials acted not solely as non-agglutinants, but as negative agglutinants. For example, a mixture of equal proportions of Arley coal and the product obtained by chlorinating Arley gave a non-coherent powder on carbonization, instead of showing an agglutinating value of 1:3 or 1:4, as would be expected. This bears out remarkably the conclusions which have been arrived at previously in this paper regarding the production, in coking coals, of highly absorbent materials which manifest a great avidity for agglutinant during carbonization.

The results of these investigations have indicated very clearly how considerable benefit may accrue, and how serious pitfalls may be avoided, in the selection of coals for carbonization purposes by laboratory control, particularly from the point of view of the valuable information furnished by the study of the agglutinating properties of coals.

Smokeless Fuel and Low-Temperature Carbonization.

No discussion dealing with the subject of coke production can be considered as complete without the introduction of the universal question of smokeless fuel and at least the mention of the present world-wide investigation of low-temperature carbonization processes.

With regard to the latter, my own view is that, taking into consideration the general financial position of the gas industry, it is certainly too much to expect that low-temperature carbonization—involving the leaving of 50 p.ct., or even 25 p.ct., of the valuable volatile products of coal in the coke, with the production of a residue and liquid products whose superior qualities are questionable, involving also the erection of new types of plant and special gear for large mechanical units—will ever prove a financially sound proposition, or is ever likely to go very far beyond the experimental stage. The fact is quite evident that financially such processes can never successfully compete particularly with the modern, almost ideal, methods of carbonization at high temperatures in continuous vertical retorts. It must be borne in mind that none of the low-temperature systems claims to deal successfully with inferior coking coals, but, on the contrary, they require the best of coking coals to produce a good coke. Recently published official tests of such processes have demonstrated that, though they have proved fairly successful in yielding the types of products which have been claimed, from the competitive financial point of view they have been failures.

With regard to the production of smokeless fuel, no better exposition of this could be given than by quoting extracts from two excellent references to the subject in the June 10, 1925, issue of the "Gas Journal." Dealing with the Gas Light and Coke Company's successful demonstration at the Wembley Coke Exhibit, it is stated (p. 728):

> The exhibit demonstrates effectively one basic fact to all and sundry, that there is no need to wait for a smokeless fuel; for such a fuel is already here, available for every purpose for which fuel is required. . . . Demonstrations of several kinds of domestic grates show that, instead of a strong draught being necessary, a coke fire burns brilliantly with a minimum amount of draught.

Further, Mr. H. D. Madden, Engineer and Manager of the Cardiff Gas Company, in a paper on "General Sales Propaganda," states (p. 737):

> Coke, the ideal smokeless fuel, when properly prepared, has received in the past but scant attention. . . . Manufacture the best coke possible by selected and blended coals, and then give publicity in the offices and showrooms. . . . It will then begin to sell itself. This method will do much to popularize, and further the uses of, coke for domestic and other work; and if carefully handled, it will compete with, and largely take the place of, anthracite in closed stoves and water-heating apparatus.

In the furtherance of this valuable propaganda work, Mr. Madden's Company have published and broadcasted an excellent little brochure pointing out and describing the multitudinous uses to which different grades of coke may be advantageously put. "Ordinary" coke is recommended for bakers' ovens, foundries, central heating, and hotel grills; "broken" coke, for open grates, kitchen ranges, steam road transport, and central heating; "nut" coke, for steam raising, greenhouse and garage heating, hot water supplies, and closed stoves; and "bean" coke is recommended for smithy forges and anthracite stoves.

It is by such propaganda work, coupled with the bestowal of due care on the processes of coke production, that the immense consumption of 40 million tons of coal annually for domestic purposes in this country will be greatly reduced; and this must naturally bring in its train the reduction of the smoke nuisance and the pollution of our atmosphere.

Ash Content.

The question of the mineral matter or ash-content of coal and its relation to the quality of coals to be carbonized is a vast and important subject, which should enter into the scope of any treatise on industrial coke production. It is considered, however, that this subject cannot be efficiently treated by any brief reference here. It has received considerable attention from numerous investigators, and has very recently been reviewed in a most efficient and comprehensive manner by Dr. R. Lessing, in a paper on "The Inorganic Constituents of Coal" ("Jour. Soc. Chem. Ind.," June 12, 1925, pp. 277T-283T), and by F. S. Sinnatt and H. E. Mitton, in a brochure dealing with "The Preparation of Coal for the Market" (pp. 56), prepared for the Empire Mining and Metallurgical Congress held in London in June, 1924. It is interesting to note in this connection that a step in the right direction has been taken in the realization of the disadvantages accruing from a coke of high "inert" content.

Recently, a conference of iron masters and coke makers at Sheffield agreed upon a sliding-scale of prices for coke, based on the content of moisture and ash, which will in future govern transactions in the Midlands, South Yorkshire, and Derbyshire. Instead of a flat rate per ton, the consumer will pay a certain price, less 10d. per ton for every 2 p.ct. of inerts (moisture, *plus* ash) above 10 p.ct. in the coke.

Conclusion.

In conclusion, several points must be mentioned with regard to modern industrial methods of carbonization, including reference to the temperatures at which carbonization shall take place, having regard to the characteristics of the coals, and reference to the quenching of coke.

An important point in connection with carbonizing plant has been referred to recently by Dr. Weyman in the paper which has been previously mentioned ("Gas Journal," June 3, 1925, pp. 665-667). This refers to the standardization of such plant. There can be no question of the advantages of installing plant in standard units which can be readily duplicated when extensions become necessary, and may thus mean a material reduction of capital charges and economy in reconstruction and repairs. The modern tendency is certainly to realize this, particularly in the case of continuous vertical retorts, which, there is very little doubt at present, are destined ultimately to replace all other systems of carbonizing coal all over the world. To the writer, it appears quite evident that no further advance in carbonizing systems can ever be expected that would be comparable to the evolution of the continuous vertical retort from the old system of intermittent carbonization in horizontals.

A. B. Searle, in "A Review of Recent Developments" (an addition to "The Carbonization of Coal" by V. B. Lewes), states:

> Perhaps the nearest of any (carbonizing systems) to the ideal are the vertical retorts. . . . Yet even vertical retorts are open to the serious objection that they do not permit sufficient control of the heating of the coal in its various stages of decomposition, and are not sufficiently adaptable to the widely differing characteristics of different coals. . . . Two lines of research are, therefore, necessary:

1.—To find a suitable carbonizing apparatus capable of dealing with any coal.
2.—To improve the existing retorts in accordance with latest discoveries in the physics and chemistry of carbonization.

The " serious objection," however, is seen to have been completely overcome, and " the suitable apparatus capable of dealing with any coal " is seen to have been achieved, if reference is made to the announcement and description of " Continuous Vertical Retorts for All Kinds of Coal " in the " Gas Journal " of March 25, 1925 (pp. 729-730). It is reported here, and has been recently abundantly proved, that Glover-West vertical retorts, for example, will deal successfully with Scotch coals, Durham, Yorkshire, Somerset, and Lancashire coals, or coal from any other part of the world. There need now be no question of having to select coals suitable for continuous vertical carbonization. All coals are suitable; there arises only the question of the economic value of the available supplies from the point of view of obtaining the desired yields of coke, gas, and bye-products. The adjustment and control of temperatures in any part of the system, and the consequent efficient control of the heating of coal in its various stages of decomposition, has now become the rule of the day. It is now a simple matter to adjust throughput and steaming in order to obtain any desired quality of gas from straight coal gas to gas of 400 B.Th.U. per c.ft., or even less, from practically any coal.

The problem of the quenching of coke is most efficiently overcome in such modern systems. Is it not the ideal way to eliminate completely the necessity for quenching by returning practically the whole of the heat from the coke to the carbonizing system, by the medium of steam, before the coke leaves the retort? There is no doubt that this constitutes a perfect example of heat regeneration.

There is certainly no need here to elaborate further the advantages of continuous vertical retorts. The literature is rich with references to them, and their adoption is spreading very rapidly.

The question of carbonizing coals at high, medium, or low temperatures has developed into a very controversial subject, particularly within recent years. The adoption of the highest attainable temperatures, with due consideration to economy and the life of the settings, appears to be gaining favour, and may be said to be keeping pace with the adoption of continuous vertical systems. The advantages of carbonization at high temperatures have been summarized as follows (J. West, Southern Association of Gas Engineers, 1917—" Gas Journal," Vol. 140, p. 314):

Advantages of High Temperatures.	Disadvantages of Medium and Low Temperatures.
1.—Requires less ground area for plant.	Requires from double to treble ground area.
2.—Requires less carbonizing plant.	Requires double to treble carbonizing plant.
3.—Requires less capital.	Requires double to treble capital.
4.—Requires less labour.	Requires double to treble more labour per ton coal.
5.—Makes considerably more gas per ton of coal.	Make of gas reduced to less than half.
6.—Makes gas of higher calorific power when illuminants removed.	Gas of low calorific power when illuminants removed.
7.—Makes better and harder coke.	Coke badly carbonized, and very friable, resulting in considerable waste.
8.—Tar and liquor not reduced, and of better quality.	Coke or smokeless fuel contains a considerable quantity of bye-products, which are wasted.

The term " high-temperature carbonization " may be taken as relating to temperatures (in the coking mass as distinct from combustion chamber temperatures) above 900° C.; " medium-temperature carbonization," to temperatures between 900° and 600° C.; and " low-temperature carbonization," to temperatures below 600° C.

It is fully realized that the discussion of plant and processes has only received secondary consideration in this paper. An attempt has been made rather to indicate the beneficial results which would accrue to the gas industry from the thorough investigation and careful selection of coals and coal mixtures, on the lines which have been mentioned, for the production of the best coke, with due regard to national and industrial economy.

APPENDIX I.

The following is a brief description of the sources, the properties, and the chief industrial uses of the four Lancashire coals referred to in this paper. Their complete analyses, carried out by the commonly adopted methods (Fuel Research Board—" Interim Report on Methods of Analysis of Coal "), are also tabulated for comparison.

Arley, the lowest seam in the middle coal measures of the Lancashire coalfield, is perhaps the most perfect and valuable seam in the field. It is essentially a mixture of vitrain and clarain, in which the latter predominates. Thin bands of durain occur in the seam, as also 1 to 2 p.ct. of fusain. The coal has good coking qualities, though not excessive, and is a valuable steam-raising and gas-making coal. It is comparatively non-fragile, and was chosen for this work as being a typical bituminous coal (para-bituminous species, according to Seyler's classification). The sample under examination was obtained from a delivery of 16 lbs. of 1 in. to 2 in. cubes from the Garswood Hall Colliery Company, Bryn, Lancashire.

Mountain Mine is the lowest important seam in the lower measures of the Lancashire coalfield. It contains a high percentage of vitrain and clarain, with practically no spore coal or durain. It is most largely used for the production of metallurgical coke, for which product it excels most other coals in the country. It has extremely high and valuable agglutinating properties. The sample, from the Low Bed of the Lower Mountain Mine seam, was obtained from a delivery of about 1 cwt. from the Executors of John Hargreaves, Ltd., Hapton Valley Colliery, Lancashire. The coal was in lumps (up to roughly 6 in. cubes), showed banding very definitely, and also distinct partings (" ankerites ") in the vertical plane. The lumps, separated so as to be as free as possible from partings and pyrites, were broken up, and coned and quartered until a sample of the required size was obtained.

Yard (Bickershaw).—This seam is practically homogeneous in character, consisting entirely of durain, except for two thin bands of bony material. In appearance it closely resembles a cannel coal. The sample was prepared from about 20 lbs. of lump coal from the Abram Coal Company, Ltd., Bickershaw, near Wigan. The coal is quite free from fusain, hard, of clean appearance, and splits with a conchoidal fracture. The bands of bony material were excluded from the sample.

Ravine (Abram) consists essentially of clarain and vitrain. It closely resembles Arley, but was chosen as a typical seam of the class which undergoes rapid spontaneous ignition in the " goaf." In fact, it is one of the seams of the Lancashire coalfield which most rapidly undergoes spontaneous heating in the mine; and many of the dangers of the coalfield are associated with the working of this seam. The sample was taken from a section of about 10 cwt. cut through the seam. The coal presents a clean, bright appearance, except for a few thin dirt bands. These bands were avoided in reducing the sample.

These four coals have been the subject of several further investigations by Sinnatt and his collaborators, published in the Bulletins of the Lancashire and Cheshire Coal Research Association. The Arley and Ravine seams have also been fully described in two recent publications of the Department of Scientific and Industrial Research, as contributions by the Fuel Research Board to the " Physical and Chemical Survey of the National Coal Resources " (Nos. 3 and 4 respectively).

It may be deduced from the analyses in the following table that Arley and Mountain Mine come in Seyler's classification under the genus " bituminous " and species " para-bituminous." The other two coals are of the same genus, but of " meta-lignitous " species. All four of the coals, under Campbell's classification of carbon : hydrogen ratio, are in the class " Bituminous 2." In this table, the " volatile matter " is given as determined by the American standard method (being the method in general vogue at present), and results such as " coke " and " fixed carbon " are deduced from this determination.

Analyses of Coal (Percentages).

—	Arley.	Mountain Mine.	Bickershaw Yard.	Abram Ravine.
Proximate (air-dry basis)—				
Moisture	1·82	0 83	2·36	2·10
Ash	1·94	11·50	7 19	2·86
Volatile matter (American method)	36·85	28·48	41·08	36 42
Volatile org. matter	35·03	27·65	38·72	34·32
Coke	63·15	71·52	58·92	63·58
Fixed carbon	61 21	60·02	51·73	60·72
Calorific value (B.Th.U. per lb.)	14,460	13,310	13,325	13,940
Ultimate (ash-free dry basis)—				
Carbon	85·12	85·00	81·61	81·69
Hydrogen	5·70	5·46	5·48	5·65
Nitrogen	1·59	1·20	2 16	1·56
Sulphur	1·50	1·66	1·35	2·36
Oxygen (by difference)	6·09	6·68	9·40	8·74
Volatile org. matter (ash-free, dry basis)	36·40	31·54	42·81	36·11
C/H ratio	14·9	15·6	14·9	14·5

APPENDIX II.

Description of Modified Lessing Furnace and Its Uses.

The following is an abridged description of the reasons which influenced the choice of a special type of furnace for use in the experimental investigation of the agglutinating and coking properties of coal, also a description of the furnace and the necessary appurtenances, and some further reference to the methods

adopted for the determinations of agglutinating value, yield of volatile matter, swelling of coal on carbonization, &c.

Reference to the literature will show that literally dozens of different methods have been adopted for carbonizing coal in experimental determinations of agglutinating value and yield of volatile matter and coke. Practically every investigator has varied the details of the determinations; every possible type of crucible has been used, and numerous methods of heating them.

In several recent papers, and particularly in the discussions which they aroused, considerable stress has been laid upon the desirability of standardizing, in particular—

(*a*) The type of crucible to be used.
(*b*) The method of heating the crucible.
(*c*) The temperature at which the test is to be carried out.
(*d*) The duration of heating.

Severe criticism has been levelled particularly at the use of platinum crucibles, because of their expense and the possibility of catalytic action of the metal on the coking mass; and, secondly, at the methods of heating by gas over an open burner or in a muffle. In both the latter cases variation in the quality and pressure of the gas, and several other causes, lead to inconsistency in results.

It has been pointed out by several investigators, and it is clearly indicated in the results given earlier in this paper, that the yield of volatile matter (and coke) is to a large extent a function of the maximum temperature involved in the determination. In other words, the determination is purely empirical, and for a stated result to be of any practical or scientific value the temperature at which it was obtained should be definitely stated. It is therefore not surprising to find that the general tendency, particularly within the last few years, has been to adopt electrically-heated furnaces, in which the temperature can be accurately adjusted and maintained.

The Lessing apparatus, which is now fairly well known, was found to be particularly suitable for these investigations; but it has been discovered to have several rather troublesome drawbacks, and these have been surmounted by the following modifications. In the first place, it was found desirable to have a furnace which could be rapidly raised to any desired temperature, rapidly cooled down, and rapidly re-adjusted to any other temperature. At the same time it should be possible to maintain it at a constant temperature for fairly prolonged periods. The Lessing furnace does not lend itself particularly well to such desired fluctuations. The conditions aimed at were attained by adopting the double-walled sheet metal container for the Lessing tubes which is illustrated in the accompanying diagram (fig. 5). Secondly, an important modification was found to be necessary in the case of the actual retorting tube (R, fig. 6) which holds the charge. The Lessing tube is made either with a flange projecting out of the furnace or in the form of a distillation tube with side arm. With these tubes it was found impossible to avoid the deposition of tar and carbonaceous residues on the parts projecting from the furnace. This proves a nuisance, as before the coke or residue can be extracted from the tube this black deposit must be scraped off or burned away.

The retort tube finally adopted was a perfectly straight, flat-bottomed, silica tube, without a flange, and of such a length that it reached almost to the flange of the furnace tube, but did not project (R, fig. 6). In addition, it was found that this tube could be most conveniently and effectively closed by a small silica crucible placed so that the curved under-surface rested on the rim of this tube and on the flange of the furnace tube (L, fig. 6). The retort tube is lifted out of the furnace by inserting the closed ends of a pair of crucible tongs (scissors type), then opening the latter and raising gently. The tube is rested upright on the asbestos board (A, fig. 7), grasped with the tongs at the rim, and placed in a desiccator to cool. By this means, the tube leaves the furnace quite clean each time during successive tests, and the coke invariably slides easily out of the inverted tube, leaving this clean enough to be used again immediately.

In Lessing's original furnace it was advised to wind the coils of the platinum spiral closer together at the bottom of the furnace tube than at the top. This would result in uneven heating of the coal charge, particularly if considerable swelling takes place during carbonization. An appreciable improvement is effected by winding regularly and evenly, as by this means a uniform temperature is maintained throughout the retort tube. Finally, it was found to be extremely difficult to obtain satisfactory results (or the advantages claimed by Lessing) in using the plunger or piston (either solid or tubular) which is advocated as a necessary adjunct to the apparatus. Several other investigators have also observed that if the piston fits loosely it becomes embedded in the mass of coke, while if it fits too well it is blown out of the tube during the evolution of gaseous products. Under the best conditions, the piston is invariably coated with a film of pitch or carbon which has to be burned-off after each experiment. The piston was therefore discarded. Its functions of displacing the atmosphere above the coal and preventing air-oxidation are carried out quite adequately by the volatile constituents of the coal and by the well-fitting silica cover at the top of the tube.

A platinum and platinum-rhodium thermocouple (with a portable indicator made by the Cambridge Scientific Instrument Company, graduated 0° to 1500° C.) was used for measuring temperatures inside the tube (R, fig. 6); the naked junction being passed through a small hole drilled in the bottom of a crucible similar to the one used as the cover (L, fig. 6). By means of this thermocouple, the rheostat R, fig. 7 (a "Zenith," 2·8 to 12 amps., 3·95 ohms), was calibrated by marks on the slider-rod to be adjustable for any temperature required in the furnace between the minimum (about 250° C.), and the maximum (about 1000° C.).

The whole apparatus, excluding the thermocouple, was assembled during the last months of 1919 at a cost well under £7, when the price of a platinum crucible (for the standard American method) was between £20 and £30. The main items of expense are the Lessing tubes, a yard of platinum wire, and the rheostat. It is estimated that the apparatus, as described, could at present be made and sold for about £7 7s.

The complete form of the apparatus, which has now been used for a considerable time, and has yielded remarkably concurrent and satisfactory results, is shown in figs. 5, 6, and 7. The curves and table (fig. 8) indicate the rate of heating-up and cooling-down of the furnace.

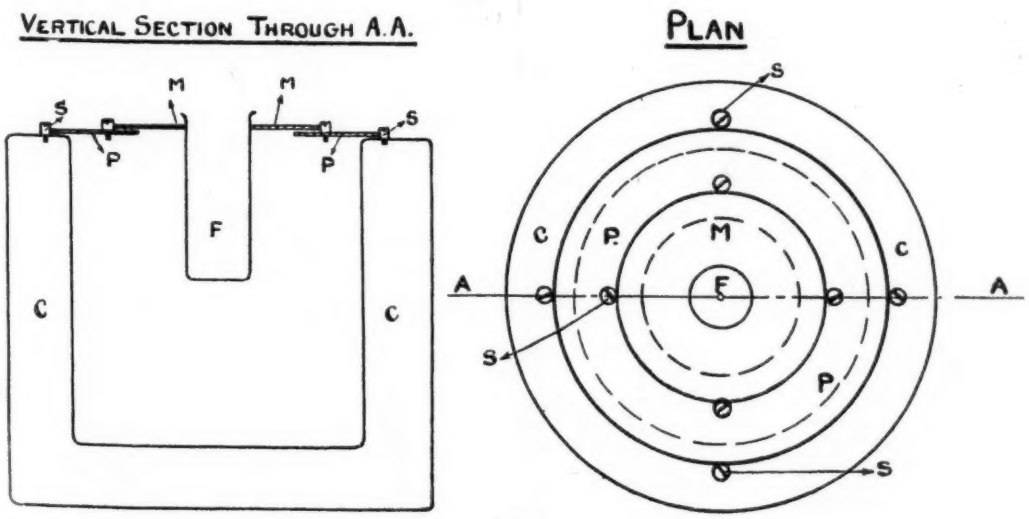


FIG. 5.

C = Double-walled, wrought-iron (0·03 in. thick) container, joints brazed, completely closed, forming a stationary air jacket, externally 6 in. high, 7 in. diam., internally 5 in. deep, 5 in. diam.

P = Circular, wrought-iron plate, 5·5 in. diam., with hole in centre 2·5 in. diam. Acts as support for M.

M = Mica plate, 3·5 in. diam., with hole in centre 1 in. diam. Acts as insulating support for F.

F = Furnace (see fig. 6).

S, S = Setscrews with raised heads, 0·2 in. diam., to keep P and M in fixed position.

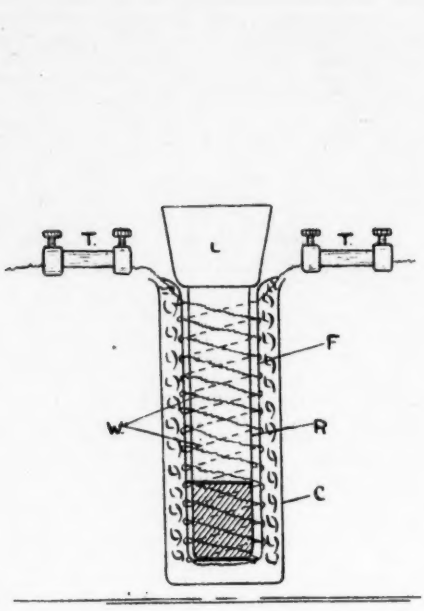


Fig. 6.

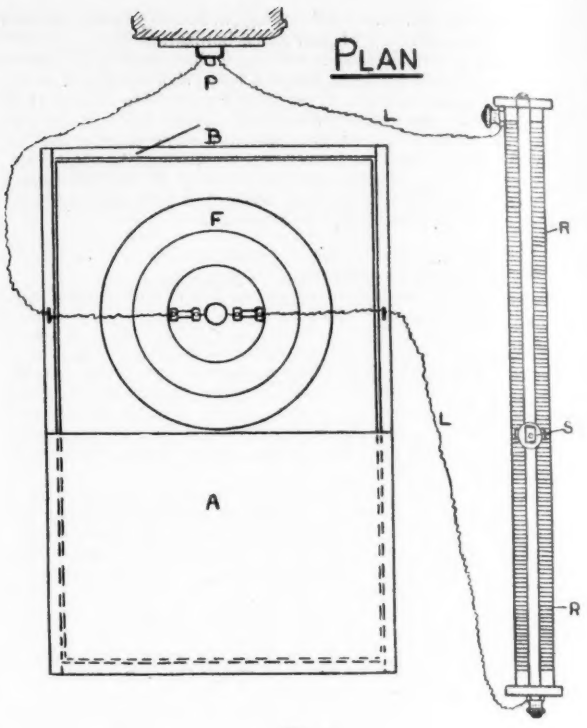


Fig. 7.

R = Retort tube of silica glass, 2·2 in. long, 0·55 in. diam. (internally), with inner walls quite smooth and parallel; weight about 6 grammes.
F = Furnace tube, silica, 0·65 in. diam., 2·4 in. long (internally), with flange. Small silica lugs are fused on regularly and evenly on outside to keep W in position.
C = Silica container fitting tightly on asbestos winding round F. It is 2·6 in. long, 1 in. diam. (externally), with flange to rest on M (fig. 5).
L = Small silica crucible resting on R and F, 0·75 in. deep, diam. top 1 in., bottom 0·6 in.
(The silica material is approximately 0·05 in. thick.)
W = 36 in. of platinum wire (S.W.G. 28, 0·014 in. diam.) first wound round a 1 mm. thick copper wire, removed, stretched to 24 in., and wound in a double spiral (insulated by asbestos cord) round R, terminating at T, T.
T, T = Brass binding screws, connecting W by copper leads to 110 volt circuit.

F = Furnace (figs. 5 and 6).
B = Wooden box (asbestos lined) 12 in. by 18 in. by 9 in. deep, holding F, which stands inside on two fireclay (or silica) bricks.
A = Asbestos board 8 in. by 12 in. by 0·15 in. thick, nailed as a part lid on to B, and used as a "working bench."
LL = Copper leads from F through R to P.
P = 110 volt plug (lighting circuit).
R = "Zenith" resistance.
S = Slider on R for varying temperature in F.

The advantages claimed for this furnace over other arrangements which have been previously described for use in the determination and study of agglutinating value, coking value, volatile matter, and coke yields may be enumerated as follows:

(*a*) Economical in original outlay and in use.
(*b*) Absence of external factors, such as atmospheric oxidation and action of gases, from heating apparatus, on the charge.
(*c*) Rapid attainment and accurate maintenance of any desired temperature between 250° and 1000° C.
(*d*) Adaptability for rapid work and, if desired, rapid change from one temperature to another.
(*e*) Uniform temperature throughout the charge during process of carbonization.
(*f*) No decomposition of volatile constituents; absence of carbon deposits in the carbonizing vessel.
(*g*) Conditions of carbonizing and resulting products more compatible with those obtaining in industrial practice because of—
(i) Substitution of silica walls for platinum, and
(ii) Production of small cylinder of coke instead of a flat button.
(*h*) Cokes produced give valuable indication of relative coking, swelling, and agglutinating properties of the coals.

With regard to the adaptability of the furnace for rapid work, several retort tubes may be used in conjunction, one being inserted into the furnace as soon as another is removed. Each 1 gramme sample is weighed out while the previous one is being carbonized, and fresh mixtures may be made up while tubes (and contents) are cooling in the desiccator. The tubes have been found to retain their smooth inner surfaces after hundreds of determinations in each, so that in this respect they are certainly not inferior to platinum, over which they have the marked advantages of cheapness and the absence of catalytic action on the charge, evidence of which in the case of platinum has been adduced by several investigators.

In the case of determinations of agglutinating value, as has been previously pointed out, the tube containing 1 gramme of mixture was placed directly into the furnace at 800° C. (or other desired temperature), and heated for exactly five minutes. For determinations of volatile matter and coke a different method of procedure was adopted. It was found that, if the

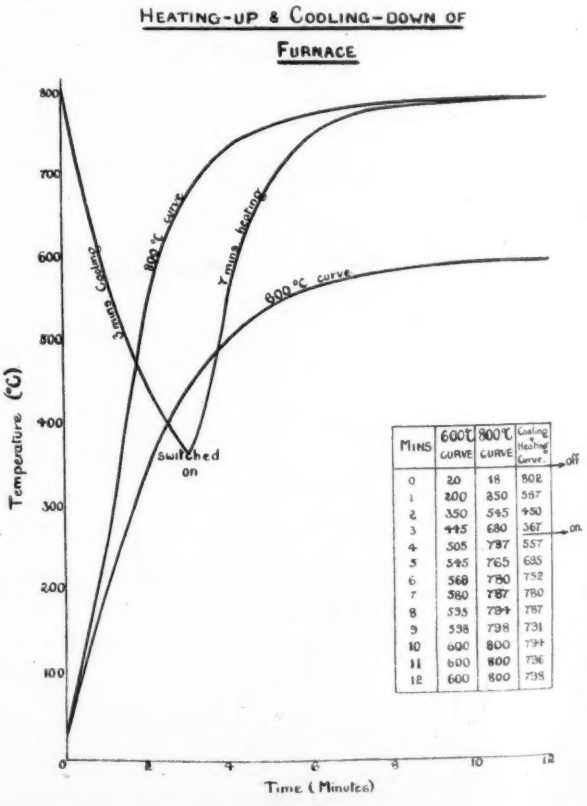


Fig. 8.

tube containing 1 gramme of powdered coal was placed directly into the hot furnace (say, at 800° C.), two difficulties were encountered. First, the rapid evolution of volatile matter tends to lift the coal out of the tube. This is overcome by gently pricking the powder in the tube two or three times with a platinum wire, immediately after insertion into the furnace, so as to initiate a passage for the volatile products formed at the bottom of the mass.

Secondly, as the top of the tube very rapidly attains red heat, there is a tendency for cracking of the tarry products, with consequent formation of black carbonaceous deposits in the tube. This is completely eliminated by the following procedure: Before inserting the tube, the furnace is switched off for exactly three minutes. During this time (see curves, fig. 8) the temperature falls about 370° C. (from 800° C.). The tube is now inserted, the furnace switched on, the coal pricked, as described above, the lid placed in position, and heating is continued for exactly seven minutes. Apparently, in these circumstances, during the few minutes which elapse before the furnace again reaches 800° C., the temperature is high enough to prevent condensation of liquid products inside the tube, yet not so high as to cause cracking of these products before they leave the tube. The coke produced by this means is invariably a clean cylinder, which slides readily out of the tube, leaving no deposits, and which is particularly suitable for comparative examination and tests.

For abbreviation in tabulating results, this method may be referred to as "3c./7h. 800° C.," while the conditions for determination of agglutinating value may be referred to as "5h. 800° C."

SECTION I.—COKE PRODUCTION.—(*Continued*).

Third Award, won by "Phalidon."

BY MR. LAURENCE HENRY SENSICLE, B.Sc., F.I.C., OF PELTON FELL.

Any compacted residue from the destructive distillation of coal is entitled to be designated as coke, but the number of different types and qualities which this material may assume is surprisingly large. Too often, unfortunately, the form which it is allowed to assume departs a long way from the best of its type attainable in the given circumstances. There are certain limited classes of coke for which a demand exists, and these mainly correspond with the number of different carbonization processes. It will be the present purpose to survey the different modes of production with relation to the various market requirements, and to explore the possibilities of stimulating such requirements by improving the quality of the coke made.

Three attitudes of mind have been, and are still, shown towards the subject of coke production. First, the attitude in which the production of coke alone from the coal, with a total disregard and wastage of the concomitant gas and bye-products, is the sole aim—for example, in the beehive coking process. Secondly, the attitude in which coke has been regarded, if not as a necessary evil resulting from carbonization, at least as only an unimportant bye-product to be sold to anyone prepared to buy without being too exacting as to the quality of material supplied. This attitude has been true of the gas industry in this country almost all the time, but signs are not wanting that a more wholesome regard for the deserts of coke as an important item in the process is growing in the industry. Thirdly, there is the attitude of the bye-product coking industry in which coke and all the aspects of quality and market requirements are considered of paramount importance, while bye-product and gas recovery is relegated to a second, though by no means unimportant, place. To this latter case might be added the new and still nascent low-temperature carbonization industry, in which the production of coke or of liquid bye-products is variously given pride of place by different authorities.

In view of the fact that coke represents upwards of 70 p.ct. of the raw material, coal, and retains about the same percentage of the heat units thereof, a dispassionate survey of the question is bound to lead to the conclusion that any attitude towards carbonization which minimizes the importance of the coke question is wrong. The history of coke manufacture is, in one sense, the history of the gas industry, and in another sense the history of the attempts to produce a blast-furnace fuel from coal, as a substitute for charcoal, which dates back to the crude carbonization of coal in heaps, and led eventually to the elaborate mechanically-operated bye-product recovery ovens of to-day.

Early Gas-Works Practice.

The history of coke as connected with the gas industry is not one of which to be proud. The early beginnings were indeed promising, but very soon developments aiming at greater and greater gas yields resulted in a neglect of, and deterioration in the adaptability of, the coke for its early established uses. Of these early uses we read that in 1819, nine years after the formation of the first gas company in London, Accum said: "The demand for coke in the capital since the establishment of the gas-light works, has prodigiously increased. Numerous taverns, offices, and public establishments, which heretofore burnt coal, now use coke to the total exclusion of coal; and in almost every manufactory which requires extensive lighting or heating, gas and coke are now the means jointly employed." There is nothing new under the sun; and this demand for coke was no other than a very early foretaste of the demand which it is now hoped will be created for the new low-temperature smokeless fuels when these are produced in quantity, or which might in fact exist for present-day gas coke if measures were taken to make it suitable.

The early gas-works process was in point of fact a low-temperature one. The coal was carbonized in thin layers in small iron retorts at temperatures which did not exceed 750° C. at the highest. The coke made would be readily combustible in the ordinary open grates, and was probably an admirable smokeless domestic fuel. As time went on, the introduction of fireclay retorts led to the use of higher temperatures whereby enhanced yields of gas were obtained. As the temperature of carbonization increased, the coke would become less and less easily combustible, and no doubt, as a result, the early demand gradually decreased. Fortunately a new demand arose for the use of the coke in closed stoves and heaters in which a more intense draught was possible. It will be well to trace the course of these changes in gas-works production up to the beginning of the present century, while a discussion of the great modern changes will be deferred until later.

About 1820 the coal was carbonized in cast-iron retorts of approximately semi-cylindrical section, 6 ft. long, and 20 in. wide. About five of these retorts were set over a fireplace in an oven heated by the combustion of small coal. Each retort was charged with two bushels of coal and heated for about seven hours to a temperature of 650° to 750° C. Incidentally the yield of gas was about 7000 c.ft. per ton of coal, and, consisting largely of primary products of distillation, would be of high illuminating power. The coke, as mentioned above, would be soft and free-burning. Next came a medium-temperature process in which fireclay retorts were used. The shape and general arrangement differed little from the original. The fireclay construction allowed the use of higher temperatures, but these were not permitted to become excessive, and probably ranged from 750° to 900° C., it being found that very high temperatures led to a destruction of the luminosity of the gas. It was not until the introduction of the Welsbach incandescent mantle that still higher temperatures began to be used. The necessity for high illuminating power began to decrease, and the desire for still higher yields of gas was attained by pushing the temperatures up. This was assisted by the gradual improvement in the quality of the fireclay retorts, and by the eventual substitution of gas-heated settings working on producer gas generated from coke underneath the settings. The introduction of regenerative methods of heating in other industries was naturally followed by the adoption of similar arrangements in the retort house. The final adoption of silica retorts in recent years may be here mentioned as the culminating point in the race for higher temperatures, in an arrangement which has not changed fundamentally from the design of the first installations laid down a hundred years ago. The coke from such horizontal retort settings naturally became less and less easily combustible, while the rapidity of heating the relatively light charges resulted in the formation of a light coke of considerable brittleness, which had a tendency to break up into small pieces and much breeze on discharging and rough handling.

It cannot be doubted that the new method of heating by producer gas was welcomed largely because this formed an outlet for an appreciable amount of the coke made, while the eventual introduction of the water gas process, with a view to enhanced gas output, afforded a further opportunity for getting rid of the unwanted coke.

Bye-Product Coking.

Though the main purport of this paper will be the consideration of coke preparation in relation to recent gas-works practice, it would be impossible to do the whole subject justice without allotting some space to the sister industry of bye-product coking. Indeed, even from the narrower standpoint of gas-making the methods of the latter industry merit attention, since there has been a noticeable tendency in certain quarters to adopt coke-oven practice in the gas-works. In a few places, notably Sweden, there exist public supply gas-works which are, in fact, bye-product coking plants producing a metallurgical coke in the usual type of coke oven. There is also to be considered the use in this country of surplus gas from many regenerative coking plants for supplementing, and in some cases superseding, the retort-house supply. Then again, on the Continent the use of horizontal and inclined chamber ovens has brought gas practice very close indeed to bye-product coking practice, the chambers being practically identical with the modern coke oven, save in respect of their being somewhat smaller.

As mentioned before, the first attempts at making a substitute for wood charcoal from coal were very crude. Heaps of coal were built into stacks in the open, and allowed to burn partially away. Part of the heat of combustion being conducted inwards, the central core was converted into coke. Needless to say, the method was extremely wasteful of heat and coal. The next stage was the enclosing of the heaps between brick walls; some control of the air for combustion being made possible by the use of flue channels in the coal and dampers in the walls. The volatile matter was not used for heating. Then came the first enclosed oven, which, being roofed over, rendered possible the admission of air over the coal, to burn the volatile matter; the heat generated by this combustion being largely efficacious in assisting the coking process. This was the immediate precursor of the beehive oven.

The beehive oven had a long era of popularity, and in fact still lingers on in some parts of the country, though, on the grounds of inefficiency and redundancy, it should have become defunct years ago. In the beehive oven upwards of 10 tons of coal are charged into a hemispherical chamber about 12 ft. in diameter and 7 ft. high. Lined with firebrick, each oven is embedded in a considerable bulk of broken bricks, slag, or the

like, which serves for the retention of large quantities of heat. The doorway of the oven is bricked-up, leaving small openings at the top for the admission of air. The volatile matter burning inside transmits heat downwards to the coal. Towards the end of the period the holes are luted-up, and the heat stored in the walls is allowed to complete the process. The process takes three days, and is thus essentially a slow coking process. It is obvious that only strongly coking coals are suitable, and these give an excellent metallurgical coke, which leaves the oven in pieces about 2 ft. long and 4 to 6 in. square in section. It possesses a brilliant metallic sheen, is compact and strong, and is much appraised by foundrymen and blast-furnace users, on account of its physical properties. Improvements in beehive design consisted in the addition of sole flues in which some of the volatile matters were burnt, and also in the utilization of the waste heat under boilers.

The first attempt at substituting a rectangular chamber for the beehive oven was a failure. This was the Pernollet oven. The aim of the new departure was to allow for indirect heating alone—*i.e.*, by admitting no air to the oven, and burning the gases in side and sole flues. Failure was due to the fact that the oven was too wide. Heating took place almost entirely from the oven sole, and then only with thin layers was the coal completely carbonized. The fact of a thin layer of coal being necessary resulted in a poor quality of coke.

The right idea was first embodied by Coppée in his rectangular chamber oven, which was only 18 in. wide and had a length of 30 ft. and a height of 3 ft. 6 in. With the exception that ovens are in general much higher now, the design has not since materially changed from that time until the present. In the early Coppée oven the volatile matter was burnt in side and sole flues; the waste heat being passed under boilers. The coke made was a great improvement on the Pernollet coke, but did not equal that from the beehive oven. In fact, it has as yet been found impossible to reproduce the special properties of beehive coke in other types of oven, but fortunately the necessity for such a reproduction is now admitted to be non-existent. Concurrent advances were made in the handling and treatment of the coke. Originally, in the beehive oven, the coke was quenched inside the oven—a procedure causing much wastage of heat, but resulting in preservation of the appearance of the coke. The coke was raked out by hand, though devices were invented and occasionally used for mechanical extraction. The Pernollet and Coppée ovens were furnished with a ram for mechanical expulsion of the coke, which was quenched outside the oven. The necessity for rapid quenching and exclusion of air resulted in the introduction of quencher hoods through which the coke passed on emerging from the oven, and, on passing through, the coke was subjected to intensive spraying with water. A further development in cooling is afforded by the recently-introduced dry-cooling systems of Sultzer and Collins respectively—processes in which the coke is pushed into a chamber, and inert gases are circulated through it until cold. The heated gases are passed through waste-heat boilers, and returned to circulation. Thus much of the sensible heat in the coke is saved. It is also claimed that the slow cooling in an inert atmosphere results in improved appearance and strength of the coke.

Apart from the introduction of bye-product recovery plant and the heating of the ovens with stripped gas using regenerative processes, the chief developments in the rectangular oven have been in the flue arrangements and dimensions of the oven, while the introduction of silica and semi-silica bricks has enabled higher flue temperatures and shorter coking periods to hold good. The latest coke oven practice aims at rapid coking in an oven as narrow as practicable, while another recent advance has been the introduction of a tapered oven wider at the base than the top. The aim of the latter has been to ensure even coking throughout the height of the oven, it being appreciated that coking usually takes place more quickly at the bottom, owing to greater heat storage of the brickwork, to sole flues, &c. The trend of progress, then, in the rectangular oven has been with the aim of abolishing sole transmission of heat, and concentrating on wall transmission; higher and narrower ovens being introduced to this end.

It is claimed by some that the latest advances have overstepped the mark in this direction, and that beyond a certain narrowness of oven, and above certain rates of coking, the coke produced is inferior in point of size and texture to the quality at present required on the markets of this country at least.

The coke made in bye-product ovens consists usually of pieces about 7 to 9 in. long and about 5 in. square in section. It is usually of a grey colour with a more or less pronounced metallic sheen, and is strong, dense, and tough. It is not so readily combustible as gas coke, and is not so suitable as the latter for many purposes. On the other hand, it is an ideal fuel for blast furnaces and foundry cupolas, and practically supplies the whole market for these purposes, for which, indeed, gas coke would be very much less satisfactory. Bye-product coke is usually made from washed coal charged to the ovens with about 8 p.ct. of moisture. The coal is generally crushed before use, and in certain circumstances compressed into a cake by a stamping machine before charging. Blending of different coals is also practised with a view to obtaining the type of coke required.

The various means for controlling the quality of bye-product coke will be discussed later in connection with the theory of coking; and in view of the long experience bound up in attempts to control quality in the bye-product industry, it is believed that these methods ought at least to be studied when considering means which may be applied to the gas industry for a similar purpose. It is highly probable that, though the types of coke made and aimed at by the two industries are different, a certain parallelism exists in the problems to be faced; and an interchange of ideas cannot but be helpful.

Present Horizontal Retort Practice.

Under this heading will be included the inclined Ω-shaped retorts introduced in 1885 by Coze, which played a considerable part in later practice, and really formed a link between horizontal and vertical retort practice. The aim of these retorts, as with the inclined chamber ovens on the Continent, was to facilitate charging and discharging. The coal was charged by gravity at the upper end, and the coke was likewise discharged at the lower end. The means of operating horizontal retorts have varied but slightly. Originally they were single-ended, and all charging and discharging had to be carried out at one end, usually by hand. The introduction of the double-ended retort enabled the coke to be pushed out by a ram or rake operated from one end; the coal being charged at the other. The retorts were for a long time charged and leveiled-off with a free space existing above the coal—such charging being carried out by shovel or elongated scoop and rake, and eventually by similar devices operated by machinery. Then came machines such as the Fiddes-Aldridge type, which throw the coal into the retort in a continuous stream, and enable the coal to be built-up to any level in the retort, and even to the roof if desired; in such cases a free space only being allowed at the ends near the gas off-take pipes. Full charging was in many instances an important advance, since it had a special influence over the quality of the gas and tended to reduce scurf deposits. It also had an effect on the quality of the coke made, which varied with the type of coal used, and was not always entirely beneficial. A discussion of these effects will be deferred to the section on the theory of coking.

Another development in horizontal retort practice, though designed primarily for the reduction of scurf deposits and for the preservation of the illuminating power of the gas, nevertheless had its effect on the quality of the coke made. This was the introduction of the exhauster, to pull away the gas from the retort and so to reduce the pressure to a negligible quantity. Much less graphitic carbon was deposited on the walls of the retort, while the quality of the gas was improved. The effect of this exhaustion, and particularly of its excessive use on occasions when the retorts are working under an appreciable suction, is, however, an adverse one as far as the coke is concerned, as it tends to reduce the amount of binding material left behind during the hardening of the plastic layer, as will be shown later. Such an adverse effect would be most likely to be felt with poorly coking coals in fully-charged retorts.

In recent horizontal retort practice the retorts are about 20 ft. long, 16 in. deep, and 22 in. wide, while the charge of coal is about 6 to 7 cwt. The carbonizing period is from 6 to 8 hours, and the temperature of the charge is allowed to rise to a temperature of from 900° to 1100° C. The final temperature allowed has an important effect on the properties of the coke, as will be seen in the sequel.

Present Vertical Retort Practice.

The history of the vertical retort dates back to 1828, when Brunton attempted intermittent carbonization in vertical retorts, but without success, owing, no doubt, to the difficulty of heating without the aid of producer gas systems. Next came the Bueb process operated at Dessau and introduced to this country about 1904. This process has been in successful operation at Sunderland, among other places. The installation consisted of six beds of ten retorts each in two rows of five. The retorts were 13 ft. 1½ in. high, expanding from 9 in. by 22½ in. at the top to 13¾ in. by 27¼ in. at the bottom. The installation coked 400 tons of coal per week, each retort taking about half-a-ton of coal, which is carbonized in 12 hours; steaming being resorted to during the last 2 hours. With steaming, the coke consumption was about 17·8 p.ct. of the coal carbonized, and the yield of gas from a Durham coal was 13,000 c.ft.

The retorts are discharged at the bottom at the end of the period, and when empty can be examined and scurfed when required. Heating is, of course, fairly uniform from top to bottom, and coking proceeds inwards from the walls of the retort. Owing to this latter feature, considerable pressure is built-up by the gas at the base of the retort, a condition which is likely to lead to a certain amount of degradation of the products of distillation, with resulting scurf deposition.

A great improvement on this intermittent process was the introduction of the continuous vertical retort—an innovation which bids fair to bring about a universal change in carbonizing practice in this country. The constructional and mechanical difficulties were great, but were successfully surmounted by the Woodall-Duckham Company (1903 to 1908), Glover-West (1905 to 1909), and later by Messrs. Dempster & Co. with their Dempster-Toogood system. Two of these systems will be briefly described.

The Glover-West System.—In an installation at Manchester are two settings of eight retorts producing in all 500,000 c.ft. of gas per day. The retorts are oval in section expanding from 30 by 10 in. at the top to 36 by 22 in. at the bottom, and have a height of 20 ft. The chief feature in this, as in other continuous systems, is the gradual descent of a column of coal which is converted into coke as it proceeds downwards. The greatest heat supply is given at the top of the retort, whereby primary products are driven off early and escape without having to pass through hot coke, thus reducing degradation with carbon deposition to some extent. A special feature of the Glover-West installation is a cast-iron chamber, 3 ft. deep, at the base of each retort, which forms a cooling chamber for the coke, and enables the heat given out to be transferred to the air for secondary combustion. Below this coke cooling chamber there is a coke extracting device consisting of a slowly revolving vertical screw which discharges the coke into the bottom hopper. The latter has a self-sealing lid and is discharged every 2 hours

The Woodall-Duckham System.—The Woodall-Duckham retorts are 25 ft. high, and expand from 4 ft. 3 in. by 8 in. at the top to 5 ft. 3 in. by 20 in. at the bottom. The heating is, of course, effected by producer gas generated from coke. This gas and the secondary air supply from the regenerator meet at the top section of the retort, and burn downwards in a spirally-guided path round the outside of the retort, which is built-up of grooved and tongued bricks. Thus the greatest input of heat to the retort is provided at the top, where it is most needed. The coal is fed in through a gas-tight hopper of mild steel arranged at one side of the top of the retort. This hopper holds a 3-hours' supply of coal, and is closed by a gas-tight valve. It can be refilled almost instantaneously. The coke extraction gear is of special design, and consists of a series of cross pieces mounted on a shaft in staggered formation, so as to produce a helical blade effect. The shaft rotates once per hour, and in so doing withdraws a definite quantity of coke from the retort. The design of the extractor is such that it is impossible for coke pieces to become jammed together in such a way that they might become broken-up during extraction.

The retort is kept full of material, since the coal feed hopper is always open to the retort and always contains a reserve of coal. A gas space is, however, provided by the existence of an iron plate fixed below, and to one side of, the hopper mouthpiece, which thus prevents the coal from passing across to the gas off-take side of the retort. It is obvious that the rate of revolution of the coke extractor device regulates the carbonization period and the rate of the coal feed.

After passing the extractor, the coke falls into a cast-iron receiving hopper which holds 3 hours' discharge. When necessary the coke can be quenched within this hopper by means of a spray of water. The bottom of the hopper is closed by a gas-tight or water-sealed door. It is clear that, owing to the shape of the carbonizing chamber, and to the fact that the mass is continually moving downwards while it is being coked, the uncoked coal will, as a result, form a wedge shape with the apex less than half way down the retort. Thus all primary scurf-producing products will escape contact with hot walls in view of the fact that they escape early, and those leaving the coal near the apex of the wedge will be sufficiently far removed from the walls to have little effect, and will, in fact, if they tend to proceed outwards, be cracked by the surrounding coke before they can reach the walls. Scurf troubles with this type of retort are very slight, and hence hanging-up of the charge is of rare occurrence. When hanging-up does occur, it is caused near the top, and can be freed by "tickling" with a rod put through a ball-sealed stirring hole at the top. The coke on discharging from the hopper can be fed by gravity into trucks or on to conveyor belts, and transported immediately to the place required, with a minimum of rough handling.

Continuous vertical retorts present many unique advantages over previous types of carbonization apparatus. Among the chief of these advantages may be enumerated the following:

(1) Ease of charging and discharging, and greatly reduced labour and machinery costs.
(2) Absence of smoke from charging and steam from quenching.
(3) The possibility of steaming for greater gas output.
(4) Constancy of gas quality.
(5) Flexibility of control and ease of adjustment of carbonizing conditions to suit different coals or for the production of different types of coke.
(6) Uniformity of coke quality obtainable under each set of pre-arranged conditions.

Theory of Coking (Recent Developments).

The behaviour of coal on heating has been studied by many workers, and a large mass of somewhat conflicting data is available for the use of the would-be theorist. The problem is complicated by the fact that coals differ greatly from seam to seam and district to district with regard to their coking and gas-yielding properties, while the mode and rate of heating, state of aggregation, size of particles, and content of moisture and ash all exert very definite influences over the course of carbonization. Dealing only with those coals which yield a coherent coke and produce a commercially satisfactory yield of gas, certain main stages of carbonization can be assumed common to all.

On heating, these coals start to decompose at about a temperature of 250° C. with the evolution of a more or less appreciable amount of oxides of carbon and water. From this point the rate of evolution varies as the temperature rises, and certain maxima of evolution occur at different times during carbonization, which have been termed by Illingworth "nodal points." These maxima vary in their temperatures of incidence with different coals and also with the rate of heating. Between 300° and 550° C. the coal passes through a stage of more or less complete liquation known as the plastic stage. The temperatures of onset and disappearance of this phase also vary somewhat with different coals and with the rate of heating, as has been shown recently by Foxwell. The temperature range of duration of this state tends to increase with the rate of heating, but is usually of the order of 100° C. The cause of this liquation is the production of tarry matters resulting from the thermal decomposition of certain parts of the coal substance.

According to Illingworth, this tarry matter represents the result of melting of the so-called gamma compounds which are dissolved out of the coal on treatment with pyridine and chloroform; but whereas these depolymerized substances melt at temperatures round about 150° C., the evidence that these compounds alone are responsible is not conclusive. According to Foxwell, the evolution of tars from the coal is low during the plastic stage; the main evolution of these substances taking place before and/or after this stage. The inference to be drawn from this is that the plastic stage is caused by the chemical formation of tarry matter of sufficient thermal stability to resist volatilization or decomposition until a sufficiently high temperature is reached. When decomposition of the tarry matter takes place at a higher temperature, there will in general be formed a residual skeleton of carbonaceous matter which binds the whole mass together in the form of coke. It is thus clear that the concluding and immediately ensuing stage is the first and most important factor in determining the formation of the coke, since, once rigidity is reached, the general structure of the mass will have been decided. The first essential, then, for the formation of coke is that sufficient semi-liquid matter shall be formed at one stage to unite or enmesh the rest of the coal material and to form a connected plastic mass. Illingworth postulates for some coals two or more stages of partial liquation, dependent, in his opinion, upon the existence of gamma compounds of varying grades of thermal stability. If the coal is heated sufficiently quickly for these stages to overlap, a coherent coke will result; while if heating is very slow, coke will not be formed. He explains this by assuming that each subsequent decomposition of a gamma compound will break-up the already formed coke skeleton produced by the previous compound. However, an equally feasible explanation would be that each stage in itself would not produce sufficient liquid medium to enmesh and unite the remainder in a plastic continuum. Sinnatt, indeed, has demonstrated the necessity for a sufficiency of this binding material by showing that some normally coking coals will not yield a coke if mixed with only an equal weight of inert material ground to extreme fineness, the reason being that, the finer the material, the greater is the amount of binding material required to cover the increased surface of the particles, and so to give them an adhesive surface for agglomeration.

Throughout the plastic stage of the coal, volatile matters are being evolved, and so tend to form pore channels of escape in the semi-fluid mass. It is thus evident that the form the mass is compelled to take by virtue of this flow of gases at the time immediately antecedent to solidification will be the ultimate general form of the coke mass. That is to say, the questions of porosity, density, structural formation, and to a certain extent combustibility and strength, will be very largely determined for good or ill at this stage. Let us consider the factors which can influence the course of this stage in the coking process.

First, the rate of volatile matter evolution will obviously affect the result; a rapid flow of gases during the onset of rigidity being likely to multiply and enlarge the pores and to result in swelling of the mass. Thus a puffed-up coke of poor strength would be made unless other counteracting factors (to be mentioned) are present.

Secondly, the rate of heating at this stage will affect the result in two possible ways: (*a*) By the obvious effect in accelerating the rate of evolution of volatile matter, and (*b*) by its effect on the proportion of binding material left behind by the plasticity-promoting tars. This is of some importance, since with the poorer coking coals anything which tends to increase the binding material is of advantage, and in this case rapid heating would tend to break-down more of the tarry matter to form carbon residuum before it would have the opportunity of being volatilized, or, as it were, steam-distilled-off in the stream of gases. In this connection it is interesting to note that many non-coking or poorly coking coals furnish a large bulk of water of decomposition at a temperature near the normal range of plasticity, and it would seem not improbable that any tendency towards coking that these coals may have is lessened by steam distillation out of the mass of some of the

binding materials which would not normally volatilize. There is strong corroboration for this possibility in the fact that some non-coking coals exhibit, as it were, a negative coking index—*i.e.*, they inhibit coking when mixed in a definite proportion with a coking coal to a greater extent than would an equal proportion of an inert substance such as sand.

Another important effect of the rate of heating is its influence over the width of the plastic layer in the retort. More rapid heating would tend to bring a greater width of coal into the plastic state at one time, and it is conceivable that, when carbonizing coal containing a heterogeneous variety of sizes of pieces, a greater width of plastic zone would help towards greater homogeneity in the coke.

Thirdly, in a list of factors influencing the structure arrived at during the onset of rigidity is the pressure to which the plastic mass is subjected. In horizontal retort practice this is usually slight, particularly with partially filled retorts. Confinement of the coal mass as in filled horizontals, and greater superincumbent weight of material as exists at the base of the chamber oven and in the lower portions of intermittent vertical retorts, will tend to submit the plastic layer to greater pressure. The effect of pressure on the layer will be to counteract the effect of other factors, mentioned above, which tend to distend the mass. A particularly striking example of this latter effect has been observed recently in the case of certain coke ovens. These ovens have sole flues in addition to the usual wall flues, and are charged to a height of about 8 ft. with high volatile coal. This, in conjunction with the rapid heating experienced near the base of the oven, might normally be expected to produce a light porous coke. In point of fact the coke near the strongly heated base has been found to be extremely dense and hard. This is considered to be due to the pressure exerted upon the horizontal plastic layer by the superincumbent weight of uncoked coal which is free to slip down and maintain the pressure. In the same ovens at the top the reverse conditions hold good, and small subsidences of the uncoked coal upon the already shrinking coke at the base enhance the loose packing of the coal to be expected at the top. Thus the plastic coal at the top is free to distend considerably, and a light spongy coke results.

A fourth important effect on the concluding plastic stages is that of the direction taken by the evolved gas and vapours on leaving the plastic layer. There are three main directions which can be taken—namely, (*a*) outwards towards the hot wall of the carbonizing chamber, (*b*) inwards to the cool core of unchanged coal, (*c*) along the plastic layer itself towards the gas off-take pipes. All these three modes of travel are represented in known types of carbonization apparatus, though, in general, two or even three of these alternative paths may be taken by the gas at the same time. (*a*) A good example of outwards travel of the gases from the plastic layer is afforded by the ordinary beehive oven. (*b*) No example of complete inwards travel of the gases exists to-day, but this mode of travel was well exemplified by Jameson's modified beehive oven. This experimental oven was heated only from the top, and was fitted with gas off-take pipes embedded in the base of the coal charge. These pipes were connected to an exhauster, and so all the gases and vapours evolved were immediately withdrawn downwards from the heated regions to cooler parts. (*c*) An example of flow of gases through the plastic layer is afforded by the modern chamber oven, since much of the gases generated in the plastic layer passes in a natural direction—*i.e.*, upwards. The plastic layer, being approximately vertical and parallel to the walls, is not under any great pressure, and readily allows the formation of vertical channel pores within it. These three examples are extreme cases, and it is important to note the effect on the coke made of the three modes of travel of the gases from the plastic layer. The ordinary beehive coke is, of course, extremely tough and well bonded. This is explicable when it is considered that the maximum obtainable carbon residuum will be left by the plastic zone tars, since any tendency to volatilize without decomposition is checked by the forced passage along an up-gradient of temperature. In the abortive Jameson experiment the coke was found to be very weak and generally unsuitable, while increased yields of tar of a distinctly low-temperature character were obtained. The inference obviously is that any tendency towards volatilization of plastic layer tars was helped by the fact that gases were passing across from the outer regions, and carrying away with them tarry matters which would be normally cracked *in situ*. In the third example we have a kind of mean between the two extremes described above. In the rectangular chamber oven the coke produced is of fair strength, but is not so good as the ordinary beehive product. Heat is being conducted into the plastic mass, while the tars are not being carried out of range, but merely pass to some extent along inside the layer so that an appreciable amount of cracking results.

A fifth factor influencing the nature of the bonded residue left after plasticity is the type of binding tar formed. This depends on the source of the coal, and Illingworth and Foxwell distinguish several types in which the plastic layer is formed at different ranges of temperature. In general the lower the temperature of plasticity the thinner will be the liquefied constituents, and the less will be the chance of obtaining a sufficient residue of solid binder. These considerations, and factors such as the quantity of liquefied product, will, of course, determine the classification of the coal as regards its coking properties.

Having now considered the plastic stage, which in general terminates below a temperature of 600° C., the remainder of the changes taking place in the retort will be dealt with. As the charge gets hotter, the volatile matter evolved is of a lower molecular formation, and consists largely of the gaseous paraffins and hydrogen; the latter being practically the only product at temperatures above 800° C. A certain amount of degradation of the gases evolved takes place with deposition of carbon on the surface and in the pores of the coke, whereby some of the latter become closed. It is held by some that the deposition of carbon considerably strengthens the coke, though this is by no means conclusively proved to be the reason for a concurrent strengthening which does in fact take place, but which can be explained in other ways. The coke, after passing a temperature of about 600° C., shrinks gradually; and this results in the production of fissures generally lying in lines at right angles to the heating wall of the carbonizing chamber. These fissures extend inwards into the body of the coke to a point where the temperature is probably about 650° C. Above 800° C. very little more weight of volatile matter is evolved, though the gas-maker often considers the volume of hydrogen recoverable above that temperature worth obtaining.

Out of all proportion to the amount of volatile matter yielded are the changes which ensue in the properties of the coke during heating above 800° C. Greenwood and Cobb have carefully studied the succession of changes in the coke structure after the primary formation at about 550° C. They find that up to about 800° C. the whole body of the coke and the cell walls shrink, while the material becomes tougher and denser, the porosity increases from 44 to 52 p.ct., and a figure of 1·87 for the real specific gravity is obtained. Above 800° C. a further slight shrinkage of the coke bulk occurs, the porosity decreases from 52 to 45 p.ct. at 1100° C. (a figure almost the same as that at 550° C.), and the real specific gravity remains the same at 1·87. The inference is that the cell walls have thickened again, and so the coke gains an added crushing strength. The thickening of the cell walls is due partly to the deposition of "methane" carbon, but not wholly so, since this explanation would be quite inadequate to account for all the thickening that occurs. It seems as if a physical change takes place, involving something akin to vitrification of the coke substance. In this connection it is of interest to note that the late Sir George Beilby demonstrated that much of the coke substance consists of a vitreous form of carbon. It seems probable that, on passing to a vitrified form at high temperatures, a slight flow of the material would take place, resulting in a thickening of the cell walls; and the extent of the change would conceivably depend upon the duration of the exposure to excessive temperatures. Unfortunately the advantage resulting from the strengthening of the cell walls is nullified by the greatly increased brittleness of the coke, which can be demonstrated by the excessive quantity of smalls produced on subjecting the coke to the American shatter test. In the case of gas coke there is a further disadvantage in that the coke is rendered very incombustible. The coke at 850° C. is appreciably stronger than at 550° C., in spite of the thinner cell walls and higher porosity; this being due to the greater inherent strength of the coke substance, which has by that time almost attained its maximum content of carbon. With reference to the over-all volume changes of the coke, Greenwood and Cobb found, in the case of the coal tested by them, that the coke at 550° C. showed an increase of 2·8 p.ct. over the volume of the original coal charge, while at 850° C. a decrease of 11·4 p.ct. on the original coal bulk had taken place between 550° C. and this temperature. Between 850° and 1100° C. a further 11·4 p.ct. reduction in volume took place, thus showing a total decrease, on carbonization to 1100° C., of 20 p.ct. on the original coal volume.

Since the deposition of carbon on the surface and in the pores of the coke has some influence over the strength, and particularly the combustibility, of the coke, it will be well to consider briefly the stages of this deposition. When the primary products of distillation pass out through the hot coke, they suffer considerable degradation. These primary products, evolved from about 300° to 550° C., consist largely of substituted naphthenes as far as the oily constituents are concerned, while the gases are paraffins and olefines. These substances suffer thermal decomposition, with the deposition of soft carbon. Such a deposit would not adversely affect the combustibility of the coke as at first formed, but on prolonged heating at high temperatures it progressively hardens.

Pictet and Bouvier have shown that these cyclic compounds exist in primary tar, while D. T. Jones has demonstrated that their thermal decomposition is sufficient to account for the benzene homologues present in high-temperature tars. It is incidentally clear that the non-passage of these compounds through a heated zone would account for the small proportion of aromatic compounds in low-temperature tars and for the low-temperature character of the tar produced in a high-temperature oven worked like the experimental oven of Jameson described previously. Bone has shown that the decomposition of the cyclic compounds mentioned above takes place at temperatures most probably lying between 650° and

750° C., and states that their degradation with carbon deposition is mainly a heat effect alone, even radiant heat being effective. On the other hand, he finds that the decomposition of methane, which does not take place until temperatures above 800° C. are reached, and then only slowly, is purely a surface effect. This latter decomposition is chiefly responsible for the metallic sheen on coke, since it brings about the deposition of a thin hard skin of graphitic carbon. Such deposits are considered to be one of the chief causes of the difficult ignition of high-temperature coke; and since they also occur within the pores, they probably reduce the general combustibility and reactivity of the coke to a great extent.

Types of Coke Required.

(1) *Metallurgical Uses.*—These are mainly supplied by bye-product coke. First and foremost comes the blast furnace; and coke for this purpose must be strong and hard, so as to stand the burden of the superincumbent charge without crushing. Recent opinion tends to accentuate the importance of ready combustibility and regular sizing. Types of oven aiming at a more evenly carbonized and more combustible product have been mentioned previously. In rare cases only—*e.g.*, chamber oven practice—will gas coke be as suitable for blast furnaces as bye-product coke. Next in importance is the foundry cupola. Coke for this purpose must be dense, strong, and hard, while ease of combustion is an unimportant point. It must also be as tough as possible, and not liable to break-up on handling into smalls and breeze. Coke for this market commands the highest price of any, and in general the best and largest pieces are specially selected for the purpose. It can only be suitably made in coke ovens. Finally there is the foundry pot-furnace; and for this a moderately strong, easily combustible coke is required. Gas coke is suitable for this purpose, and, in fact, supplies a large proportion of the demand.

(2) *Domestic and General Heating and Steam Raising.*—A large field exists here for coke consumption, but certain variations in the types of coke are necessary. Gas coke is admirably adapted for all these purposes, if carefully prepared to suit the market. Fair strength and absence of breeze is important in all cases, while ready combustibility is only necessary in those instances where a low draught is alone available. Central heating systems, closed stoves, &c., will burn a relatively incombustible coke; but for open grates, even of the downward draught type, good combustibility is most important. The new "Sandwich" system of firing coal and coke together has opened up great possibilities for the use of coke in steam raising, and large quantities are now consumed in this way by electric power generating companies.

It is unlikely that in this country the open grate will be superseded by the closed stove, and hence the necessity for popularizing the combustion of smokeless fuels in domestic fireplaces is great. It would be out of place to enlarge upon the evils of the existing smoke pollution of the air of our cities due in greatest measure to the domestic fire, or to point out in addition the wastefulness thereof; the subject is ever present. It is not out of place, however, to remark that the gas industry has a solution, both of this problem and of the difficulty in disposing of its coke, in its own hands. The low-temperature process aims at the production of a smokeless fuel for domestic consumption, but it has been found that relatively high-temperature processes such as are used in the gas industry can produce a coke suitable for the same purpose. The flexibility of the continuous vertical retort affords the solution, since with its aid two, or perhaps three, grades of coke could be made to supply the various domestic, steam-raising, and metallurgical demands available. The domestic purposes coke could be made without recourse to temperatures as low as those aimed at in the existing low-temperature carbonization processes, as will be shown later.

With regard to the present subject of market requirements, it is important to draw attention to a much neglected point—namely, the chemical composition of the coke with special reference to its ash and sulphur contents. For domestic use, in particular, high sulphur is objectionable, while a high-ash coke is most undesirable for all purposes. In the first place, ash is an adulterant, and entails payment by the consumer for a considerable amount of useless material. Secondly, high ash leads to much trouble in disposal of the residues from combustion, and in the case of the domestic fire is anathema to the housewife, as being a producer of dust. Much more could be done in connection with this question of ash content. The bye-product coke manufacturer has for a long time been compelled to keep the ash content of his coke within reasonable limits, and has generally found it necessary to resort to washing the coal received before charging to the ovens. The wet washing processes used for coke oven work are not suitable for the gas-works unless some form of coal dryer is installed; but such processes are now unnecessary, since there have been recently introduced reliable dry washing processes. Whether adopted at the colliery prior to dispatch of the coal, or at the gas-works itself, the necessity for the adoption of such processes would seem to be great.

An excellent American process for dry-cleaning coal has recently been introduced in this country. This is the Sutton Steele Table method of coal washing, which, in the opinion of the writer, formed as the result of observing an experimental installation in actual operation, is destined to justify many of the claims made for it by those interested in it. In view of the great probable value of this new method to the gas industry in connection with the question of improved coke quality, a description of the process will perhaps be of use.

The process is really one of air flotation, and can best be described by quoting from a report by the English makers upon an American installation, as follows:

> Essentially the apparatus consists of an air box with a finely perforated deck set at an angle, so that the coal will flow down it. At right angles to the direction of flow of coal are numerous riffles or ridges about ¼ in. high, and the table is moved forwards and backwards rapidly in a direction parallel to the riffles. A motor-driven fan supplies the air through a flexible inlet, and the table is adjustable so far as the angles of slope are concerned. The principle is that, when a thick bed of coal is on the table, an air film is formed underneath the coal, which is lifted off the deck, and dances. Through the action of specific gravity the heavy particles settle at the bottom, and the material stratifies. In view of the fact that the specific gravity of stone or shale is greater than that of coal, the stone goes to the bottom and rests on the deck, where it is jigged to one side along the riffles until it is clear of the coal. It will be understood that ordinary coal washing depends on the difference in specific gravity of coal and stone, and this dry process is sometimes described as air washing.
>
> The products consist of (*a*) clean coal, (*b*) a middle product consisting of coal, stone, and band with coal attached, and (*c*) refuse. These are separated into chutes by arms. By adjusting these arms the amount of stone in the product can be varied to suit the requirements of particular contracts or market conditions.
>
> At the test plant the table was cleaning coal which had been sent in from a Company in Pennsylvania who desired to eliminate wet washers from their coke-making plant. The size being handled was from ½ in. to ¼ in., and the separation was excellent. The deck was later changed, and coal between $\frac{3}{32}$ in. and ⅛ in. was cleaned with similar excellent results. There is no other process save wet washing which can deal with such small coal, and the speed of separation was quite extraordinary, the capacity of the tables being as follows:
>
> 1 in. to 2 in. coal 25-30 tons per hour.
> ½ in. to 1 in. ,, 20-25 ,,
> $\frac{1}{16}$ in. downwards 12 ,,
>
> Air consumption for smaller sizes of coal about 750 c.ft. per minute at $\frac{1}{16}$ in. W.G. = 0·003613 lbs. per sq. in. Large sizes up to 3000 c.ft. per minute at 3½ in. W.G. = 0·1265 lbs. per sq. in.

In connection with the possible application of the process to the gas industry, very optimistic claims are made. It will be of use to quote again from the same source with reference to these possibilities:

1.	Freight on coal per 1000 c.ft. gas . . .	Decrease.	
2.	Coal handling at works per 1000 c.ft. gas .	,,	
3.	Weight of coal charged ,, ,, ,, ,, .	,,	
4.	Coke used in settings ,, ,, ,, ,, .	,,	
5.	Purification costs ,, ,, ,, ,, .	,,	(Note A)
6.	Cost of operating producers ,, ,, ,, .	,,	
7.	Cost of producer repairs ,, ,, ,, .	,,	
8.	Clinker removal and disposal ,, ,, ,, .	,,	
9.	Amount of gas remaining in coke per 1000 c.ft. gas	,,	
10.	Coke yield per ton coal charged . . .	Increase.	
11.	Carbon content of coke	,,	
12.	Coke available for sale per 1000 c.ft. gas .	,,	
13.	Value of bye-products per ton of coal . .	,,	
14.	Gas output per setting per hour . . .	,,	(Note B)
15.	Sundry benefits	,,	(Note C)

Note A.—Purification costs would come down only when a reduction in sulphur was effected.

Note B.—This would increase for obvious reasons, but also on account of the regularly higher setting temperatures obtainable with the low ash coke resulting from the cleaned coal.

Note C.—Cleaner and more regular coal would require less gas storage capacity. Large gas companies are, at times, only an hour or two in front of consumption with their output; and faced, as they are, by the prospect of clinkered producers with consequent low setting temperatures and poor yields occurring simultaneously with a peak consumption, additional storage has to be provided solely to cope with high and irregular ash contents. Another advantage which would accrue from clean and regular coal would be that gas undertakings could work to their declared thermal value with a small margin of safety. To make this more clear—let us suppose that a company declare at 500 B.Th.U. and sell at 11d. per therm. Owing to the risk of the calorific value falling below the standard, they average 510 B.Th.U., which they drop to 505 on changing to clean and regular coal consignments. In doing this they are effectively increasing the value of all meter readings by 1½ to 2 p.ct. which was previously being given to the consumer. These are, of course, only round figures. Further, the load on the water gas plant would be steadier with regularly cleaned coal; and hence greater economy would be obtained. Most of the savings noted above are small in themselves, but considerable in bulk; and regularity of working alone, in a continuous process such as modern gas making, will show a good return.

The makers appear to be, perhaps, over-enthusiastic with regard to the advantages accruing to the gas industry; but this does not alter the main fact that clean coke for sale purposes is

eminently desirable, and that this new process of dry cleaning may prove capable of filling a long-felt want in the gas-works.

Control of Coke Quality in the Gas-Works.

The first obvious step to be taken in aiming at suitable coke quality is carefully to choose the coal used. The gas manager has not the wideness of choice open to the coke oven manager, since he has to pay attention to the gas-yielding qualities of the coal in addition to its coking properties. In the coking industry it has often been found that blending of coals can be resorted to with great benefit. In this way many coals which would singly be unsuitable can be profitably used by admixture with coals which are, perhaps, even too strongly coking. Then again, swelling coals can be mixed with coals that tend to shrink, and so a normal product can be produced. Apropos blending, Illingworth has found that for low-temperature processes blending is extremely useful. He blends coals with fairly widely differing nodal points, so as to ensure that the evolution of gas is not excessive towards the cessation of plasticity, and so reduces swelling of the charge to a minimum. An important point to remember is that, for satisfactory blending, perfect admixture must be attained, which necessitates, primarily, fine crushing, in addition to the usual mixing devices, such as mixing bunkers with rotating disc feeds and the like. Coal is usually crushed to some extent after arrival at the gas-works, and this is the more necessary when unwashed coal is used, since the presence of nodules of shale weakens the coke, besides spoiling its appearance.

In choosing coals for carbonization, the type of process should be borne in mind, because, for example, a poorly coking coal will not give good results save in cases where coking is rapid or where the primary tars, &c., are forced to pass through the hot coke. For a poorly coking coal blended so as not to swell appreciably, the partially filled horizontal retort would probably give the best results. With strongly coking coals, on the other hand, the rate of heating will not be so important, but swelling is still a factor to be considered.

The control of the carbonizing process after the coal is charged should depend upon the type of coke it is desired to make. In all cases strength is a desideratum, and this will depend, as shown on a previous page, upon the amount and distribution of the residuum from the liquated compounds. With a good coking coal this factor need not be seriously considered, since no existing gas process has the drawback of the Jameson oven—*i.e.*, that of sweeping away the volatile matters from the plastic layer towards a cooler region. Slight tendencies towards such a happening are shown in the continuous vertical retort, and are evidenced by the lighter and more paraffinoid nature of vertical retort tar. However, much of the primary products travel up the V-shaped plastic layer, and so remain long enough to be sufficiently degraded to residuum.

Poor coking coals, however, should seemingly be avoided with continuous vertical retorts. In the case of intermittent vertical retorts the plastic zone should be truly vertical, and still more of the products will traverse the layer, while the back pressure at the base will tend greatly to strengthen the coke formed there. It is conceivable that the intermittent vertical will produce a coke that varies somewhat in strength and porosity from top to bottom.

In the filled horizontal retort the gases will not pass out towards the walls of the retort to the same extent as with the partially filled horizontal retort, and some may be expected to take a middle path through the cool coal core, while others, especially in the upper half of the chamber, will take a path along and within the plastic layer to the gas off-take spaces at the ends. High-volatile coal and high rates of heating—both factors which tend to distend the coke—can be used with filled horizontal retorts without producing an excessively porous coke, since confinement of the coal bulk is afforded by the walls of the chamber, and the plastic zone will be under a certain amount of pressure.

Further factors which diminish strength of the coke are high porosity and over-coking, the latter really causing brittleness and a tendency to break-up, giving small coke and breeze. Where ease of combustibility is not a *sine quâ non*, the final temperature of the charge will not be so important, while a tendency to form a very dense coke will not matter. Thus an intermittent vertical working at high temperatures, and the usual horizontal (fully and partially filled) retorts, will all produce satisfactory cokes for foundry pot furnaces, closed stoves, central heating, &c. For ease of combustibility, the physical changes, coupled with graphitic carbon deposition taking place above 800° C., should be avoided as much as possible. It may also be here mentioned that higher porosity will often be coupled with greater ease of combustion.

It would seem then to be necessary for the gas manager to forego the yield of hydrogen obtainable between 800° and 1100° C. if he wishes to produce a moderately combustible coke. This yield of hydrogen only represents about 1 to 2 p.ct. of volatile matter left in the carbonized residue, and at best reduces the calorific value of the straight-run gas while increasing its bulk. The vertical continuous retort seems to be best adapted for the production of combustible coke, and it is here suggested that a coke suitable for the open domestic grate could be made by this means. To this end the flue temperatures and rate of travel of the material through the retort should be so adjusted that at no point does the coke attain a temperature above 800° C., at the same time, however, ensuring that the whole of the charge is regularly carbonized by arranging that no part should fail to reach a temperature of at least 750° C. The input of heat at the top of the retort should be made as great as possible, so that the early stages up to the onset of rigidity will be brought about quickly. By this means the plastic zone will not be allowed to extend so far down in the retort that the superincumbent mass of coal would compress it enough to cause a dense, insufficiently porous coke. Such a process will still be a medium high-temperature process, and will only entail the non-recovery of low calorific value gas constituents, which loss will be very satisfactorily counterbalanced by the fact that the coke will be regularly carbonized, porous, and unsubjected to temperatures above 800° C.—all factors tending towards ease of combustibility, satisfactory strength, and suitability for domestic use.

In experiments upon the ignition temperature of coke, G. Weyman found that the zone of combustion in a vertical column of coke could be made to ascend and descend the column by reversing the direction of the air supply as many as four times without completely consuming the body of the coke. The inference to be drawn from this is that the coke consists of portions of varying combustibility. The first passage of the combustion zone would consume the most readily combustible material, while each succeeding passage would burn out the next in order of combustibility, and so on. This seems to have a bearing upon the question of steaming in vertical retorts. It appears likely that steaming would tend to attack the more reactive portions of the coke first, and so to reduce the general ease of combustibility of the body of coke. Again, having regard only to coke quality, steaming is deleterious, since it increases the ash content of coke. Thus, attractive as steaming may be from the standpoint of gas making, it would seem to be hardly worth while when the aim is to make a readily combustible domestic coke.

Conclusion.

The preparation of coke falls under the heading of another subject, but it is perhaps allowable to mention briefly the importance of care in handling the coke after its expulsion from the retort. Excessive moisture should be avoided in quenching, while storage under cover will be advantageous for the same end. The coke should in all cases be gently handled and not allowed to drop from any considerable height on to hard surfaces. It should, in addition, most certainly be sized for sale, since regularity of size plays a great part in promoting ease of combustion in all circumstances. These matters can be attended to by careful selection of the coke handling, quenching, conveying, and screening machinery.

It would be impossible, whatsoever the length of the paper, to lay down suggestions for coke improvement under all conditions likely to arise. The main problems only have been here dealt with, while a somewhat more lengthy treatment has been given to the latest results of carbonization research and the theory of coking. A critical survey of all the available data on the various aspects of the behaviour of coal when carbonized under different stereotyped conditions should enable the works carbonizer to solve the problems bound up with the working of his own plant.

There seems to be little doubt that much more attention could profitably be given to the working of the gas retort for the production of suitable coke, as well as for the production of gas, which latter aspect of the process might conceivably be given a well-deserved rest for a period. Stress is laid upon the necessity for considering the market which is likely to be available, and upon the fact that at least two or three types of coke will probably be required.

The various low-temperature processes have not yet proved commercially satisfactory; and if the time arrives when such schemes are sufficiently improved to become sound financially, it should be borne in mind that the gas industry is admirably adapted to absorb the new industry. This is true since each gas-works is situated in the heart of the market districts for smokeless fuel—namely, the homes of the town dweller—and has, in addition, the machinery of distribution already partially developed.

In the meantime, now that the need for smokeless fuels and the abolition of smoke pollution of the atmosphere are becoming matters of public politics, the gas industry should be alive to its opportunities. It has been shown above that the gas-works can make a coke at about 800° C. and containing incidentally about 3 p.ct. of volatile matter, which, although, perhaps, not so readily combustible as a true low-temperature fuel, can be used in the domestic open grate. It would be necessary, of course, to educate the public as to the possible use of such a fuel, and to convince possible consumers by extensive propaganda and by public demonstrations of the coke in actual use.

Then again, much more attention could be paid to the coke for markets already existing, which have recently shown a tendency to decrease, owing partly to an encroachment by the bye-product coking industry upon previous preserves of the gas industry. Attention should be given to the strength of the pro-

duct, to freedom from ash and other impurities, and to sizing and appearance.

Most gas companies are essentially gas light and *coke* companies. The gas industry has almost outlived the era when it depended for its existence upon the supply of light, a feature of activity which is now largely vested in electricity supply companies. The gas industry, however, continues to thrive and expand as a result of its efforts in the direction of the supply of heat—*i.e.*, therms in the form of gas. Gas companies are becoming more and more heat supply companies. May not the time arrive when most of the country's demands for heat supply in *solid*, as well as gaseous form, are left in the hands of the gas industry to satisfy? The reply rests with the gas industry of to-day. Mr. E. V. Evans has recently promulgated a doctrine that the chief aim of the gas manager should be to obtain the largest possible obtainable gaseous therms from the coal carbonized. After a thorough exploration and development of the domestic coke market, it is conceivable that Mr. Evans' dictum may well prove to be a short-sighted one, and that the policy advocated by the late Prof. Lewes was nearer the ideal, though it is now perhaps considered a little out-of-date. The new "maximum therms" policy is an advance on the old "maximum gas volume" fetish, but is still to some extent fallacious. No better conclusion could be made to the present paper than to quote a statement made by Lewes in criticism of the old gas-yield ideal, which, if applied against present-day aims, would be almost equally true to-day. His opinion was worded as follows:

> "During the last few years the statement has several times been put forward that 'as the gas manager's end and aim is gas, it is his duty to obtain the greatest volume possible per ton of coal'; but with this I venture to disagree. The gas manager's duty is to obtain the greatest possible value per ton of coal, and until every industry dealing with coal recognizes that in this respect their end is the same, little economy will be possible in our rapidly diminishing store of coal."

SECTION I.—COKE PRODUCTION.—(*Continued*).

Fourth Award, won by "High-Low Game."

BY MR. HERBERT JOHN TOOGOOD, OF ELLAND.

A PROFITABLE SOLUTION OF THE SMOKE PROBLEM.

Gas-Works' Opportunity.

In an industry such as the gas industry, which has long since passed its centenary, the most potent force in the success of a continuous problem (such as the regular and profitable disposal of the surplus coke of gas manufacture, as produced, and without accumulation of wasteful stocks) is a clear, steadfast, and farseeing vision in those who guide its destiny. Such a desirable policy can only be brought about by propaganda and enthusiasm, acting simultaneously over long periods, in order to keep the ideal always fresh before the multitude of minds, and in order to foster and maintain that popular support so necessary to sustain commercial success against all comers.

Looking backwards, a great opportunity was missed when Government monopolies were granted for the distribution of electric current, because raw coal is almost universally burned under steam boilers for the generation of all this electrical energy. Had the vision existed at that time, and had the propaganda been such as to have insisted on the burning of gas-works coke (coal residue) for the generation of this public supply of electricity, what enormous saving would have been effected in coal conservation and recovery of residuals of carbonization; what benefits would have been effected in the hygienic improvement of the atmosphere of our industrial centres in which we live, and move, and have our being.

Again, at another period in our history, when coke ovens were being developed to manufacture hard furnace coke, or metallurgical coke, then did our forbears, lacking true vision, look on askance, and allowed these coke ovens to develop independently of the gas industry; so that to-day the coke-oven industry has grown so formidable that it competes seriously in our residual markets, absorbs and tightens the market for gas coals or coking coals, and uses our gas industry to dispose of its residual gas. And now that the metallurgical coke market is slack, it has the temerity to endeavour to produce gas-works coke in its ovens, in order, during trade depression, to sell in the gas-works coke market, to our serious economic disadvantage.

The Electrical Industry.

This retrospection is useless unless it enables us to look at the present position with a clearer vision, and with a greater understanding. Introspectively can it be said otherwise than that we are "in a wood, and cannot see the forest for trees," inasmuch as, even at this present time, the propaganda of the gas industry, relatively to that of the electrical industry, is ineffective? For example, the minds of our politicians are already warped, so that they see a mirage, wherein everything electrical is lovely and right. The British public are also innocently allowing fashion and plausible small-talk to lead them, instead of the stern, hard, and irrefutable facts of economics.

When we, of the gas industry, have made the public realize that in Britain electricity is but a bye-product of coal; that the present and future prosperity of industrial Britain depends absolutely on the best use being made of her coal; and that it is the gas industry, not the electric industry, which utilizes coal with the utmost efficiency, and gives in addition the boon of a smokeless and sulphurless atmosphere—then, and then only, will come the general and irresistible demand to gasify (not electrify) the country, and erect super gas-works. Therefore the first duty we owe to the gas industry, and also the first important step to increase seriously the sale of gas-works coke, is for all to become propagandists, and broadcast the true economic facts, and the great national efficiencies possessed, and immediately obtainable by, the development of gas instead of electricity. Also to demonstrate that the distribution of electrical energy by public funds is not the panacea for all ills, but, on the contrary, it can be, and is, calculated as being likely to be carried too far, so that national waste of public money, and destruction of our great national heritage, British coal, will ensue, and withal a continuance of grime and smoke and lack of a bare sufficiency of sunshine in our industrial centres.

A popular fallacy born of human frailty—to love the young, and despise the old—exists among the rising generation that gas is gradually being replaced by electricity. This evil canker at the very foundation of truth should be disproved by every possible means by all concerned, and at every turn, and by the reiteration of the basic facts and world proofs, viz.:

1.—One London gas-works alone (Beckton) sends out energy in the form of gas exceeding the total energy from all the public supply stations throughout Great Britain. Allowing that there are 800 additional British gas-works, the immensity of the gas industry may be visualized.

2.—There are throughout Britain seven gas street lamps to one electric street lamp.

3.—On the basis of providing heat, electricity must be sold at ¼d. per Board of Trade unit to equal gas at London's price, 8½d. per therm, which (to those who think) is economically impossible of achievement, no matter how big the electrical dream of super-stations.

4.—British gas-works at the present rate of growth will double themselves in twenty years; and it is to find an economic and efficient outlet for this additional 10,000,000 tons of coke per annum that propaganda in all forms, to correct and enlighten public opinion in favour of gas-works coke, is so necessary.

5.—Fifteen years ago, Japan, having many waterfalls, had cheap electricity in many homes and workshops, and no gas, and was therefore exactly where our dreamers, the electricians and politicians, would have Britain to-day. At that period, in all Japan, there were but five gas-works, and Japan was importing tar, tar derivatives, ammonia, and other residuals of carbonization. Japan, realizing her mistaken national policy, set to work with characteristic energy to rectify the fault. To-day, Japan has 150 gas-works, is free of importing (and is actually exporting) products of carbonization, and withal she has in this same period actually augmented her supplies of cheap electricity—so much so, that the percentage of the population using electricity in Japan is about three times as great as that of Europe. Thus this world example shows that the welfare of a nation requires the development of both gas and electricity, in accordance with its own particular national endowments, on a strict and impartial basis—*i.e.*, without artificial boosting by political action.

6.—Reflecting on the relative advantage to a country of gas and electricity, think of the United States, and ask: Could America, with her comparative youth, have risen to such rapid and great eminence in the world of industry but for the natural gas with which kind Nature had so richly endowed her? Are not the United States an example to the world of the advantage of development of a country's particular endowments, and also of the magic power of propaganda when coupled with real efficiency?

7.—South Africa has practically no waterfalls, but abounds in cheap coal—9s. a ton in many centres—hence electricity is very cheap, and whole towns and districts have electricity to the total exclusion of gas. Thus, according to electricity propaganda, South Africa should be the ideal place for cheap and efficient industry; yet the contrary is the case. The prices of tar, sulphate of ammonia, and the host of derivatives from the working-up of the residuals of carbonization, are such as to hamper, in many complex ways, the development of the country—so much so, that South Africa is realizing the economic fault, and gas-works are being installed; the gas load in view being the cooking load and furnace work.

8.—Therefore, while the economists of the world are busy adopting gas, the old country, Britain, which already has the boon of the finest supply in the world, is in danger of being falsely led, by a dangerous fashion, founded on a misguided popular fallacy.

9.—Lastly, remember the old truisms: "Example is better than precept," and "First put your own house in order," before beginning propaganda work. In short, Britain, as no other country, depends upon coal. Since cheap coal in Britain has run its course, the dearer coal becomes the less efficient becomes electricity, and the more efficient becomes gas; therefore the greater the need for progress of carbonization. So that, speaking on economic grounds, we are actually entering upon the real gas age; but the country does not know it, hence the need for still more vision and propaganda into the right-guiding of our policy.

Low-Temperature Plants.

Of late years low-temperature carbonization has been the spur to invention from without the gas industry. By repeated trials and failures, these inventors, while making some technical advances, have obtained what possibly is of equal importance to progress, a great psychological victory; for, in contradistinction to that of the gas industry, low-temperature carbonization has caught the public fancy, and Government sympathy has been successfully sought. So that Government money is actually being spent in low-temperature carbonization

research; and to those with eyes to see, low-temperature enthusiasts are flirting with the Government's electrical advisers, to the disadvantage of the gas industry and the common weal. Therefore, if we would benefit by past experience, the time is ripe for action, and for the operation of that broader vision, which, rightly construed, means: We must cease to alienate from the gas industry that which rightly and economically belongs to it—viz., carbonization at any temperature, *high or low*, and all the products arising therefrom.

Realizing that gas-works at present dispose of 10,000,000 tons of coke per annum, and that householders consume or destroy 40,000,000 tons of raw coal per annum, it will be easy to visualize that the domestic fuel trade is the one great, immediate, and permanent outlet for gas-works coke. Moreover, the trade is at the door of every gas-works. Allied to this trade in domestic fuel is the spur to action of performing a real national service in increasing the benefit of sunshine in our industrial towns by reducing the smoke pollution of the atmosphere. To accomplish this task, we must remember that the public fancy already exists, so that we must produce the class of domestic fuel desired, always remembering that:

(1) Coke production transcends in importance.
(2) Coke preparation, and
(3) Coke sales; since, relative to its market, a coke well produced is a coke already prepared, and a coke half sold.

To give but one example: A free-burning smokeless fuel need not be broken and graded, but can be fed to the fire in larger and smaller pieces exactly as coal now is, thereby saving the cost of breaking, screening, and attendant wastage by breeze formation.

The subject-matter of this paper, briefly defined, is to conjure before the vision a change in gas-works practice, and by constructive thought to show how, with practically no expenditure of capital, to apply apparatus to present-day gas-works retorts, whereby the technical knowledge accumulated in recent years in low-temperature carbonization may be immediately applied and utilized to any extent *ad lib.* in existing high-temperature carbonization plants throughout the gas-works of the country, to produce chiefly domestic free-burning smokeless fuel. As is well known, gas-works, in their efforts to produce and maintain cheap gas, buy the cheaper, and consequently inferior, coals, and carbonize these coals *en masse* at high temperatures, to the detriment of the free-burning qualities of their residual product, gas-works coke, when used for domestic purposes and in existing open domestic grates.

To increase gas-works efficiencies from the handling point of view, the retort charges of coal grow ever larger, so that modern single-machine charges are approximately 1 ton of coal per retort. To carbonize this increasing mass of coal within economically reasonable time, higher and higher temperatures are necessary, so that a temperature of 1400° C. (2550° Fahr.) is used. To withstand these higher temperatures, improved and more expensive refractories are needed—viz., 95 p.ct. silica. To safeguard the working with these higher heats, higher-skilled and more expensive supervision are demanded. Thus has a vicious circle been established, around which overall efficiency is chased, while the hidden core, or blind spot of the circle, is that by the combined operation of higher heats, increased mass, and time limit, it is, after all, not really high-temperature carbonization, but instead (relative to the coal substance) a 1000° C. (1830° Fahr.) carbonization for the average of the mass of coal at the most—or something not so far removed from low-temperature work as to prevent our view-point of the desirability of domestic cellars as the happy dumping ground for gas-works coke.

For over twenty years experiments in the manufacture of low-temperature coke have proceeded, and during the latter decade much technical knowledge has been gained; but no commercially profitable case has, according to general consent, been established. To grasp commercial success, larger and still larger low-temperature installations have been erected, and much public money has been spent (possibly a million pounds). Many variations in detail have been tried out, the temperatures in use have been raised, and yet no profit account has consistently been shown or proved.

It would therefore seem that low-temperature plants, when isolated from gas-works, have likewise been moving in a vicious circle, and must court considerable inefficiency in the difficulties of disposal of their residuals, gas, tar, and ammonia, and also in the efficient handling and economical sale and distribution of their prime product, low-temperature coke or semi-coke. If so, then as a natural consequence commercial success in the providing of the desired domestic smokeless fuel can only come by merging its production and sale with gas-works procedure and plant. With this end in view, a careful and constructive study of the many and various low-temperature plants, and the literature of carbonization that has been published in the Technical Press, both from within and without the gas industry, will enable the skilled carbonizer to select from the whole the salient and useful features of both plants and processes, and array them for critical survey and steady assimilation somewhat as follows.

Domestic Coal Fire.

The popular mind believes that coal burns when placed on the domestic grate. It is necessary therefore to our subject to visualize exactly what happens. Coal does not burn, but what occurs is that the heat engendered in the spaces between the cobs of coal, by radiation, impinges on the coal surfaces, thereby liberating coal gas; and it is the gas which freely ignites and burns, thereby maintaining the heat to render the process continuous. Therefore the coal-fire is not a fire as generally understood, but is a crude (very crude and wasteful) form of gas producer, or, more truly defined, a smoke and dirt producer, which gives-out some small proportion (something less than 20 p.ct.) of the heat of the original coal consumed. Were it not a producer, the household fire could be lighted with a single lump of coal, or coal slack, which we all know from early experience is absurd. Nevertheless, let us not forget that, in spite of its inefficiency, a coal fire burns with optimistic cheerfulness, and is dear to the heart of the British housewife.

Domestic Coke Fires in Open Grates with Gas-Works Coke.

Here the analogy is precisely the same as with the coal fire, with this all-important detail difference. Gas-works coke having already passed through a 1000° C. (1830° Fahr.) stage in the process of manufacture, no gas will be liberated from the coke in the domestic grate until the surface of the coke-pieces attains approximately the temperature of manufacture—viz., 1000° C. (1830° Fahr.). Hence the difficulty of igniting and maintaining at a bright glow the small handful of gas-works coke which usually constitutes the household open fire. Moreover, be it noted, the gas, even when released from the coke, does not burn with a luminous flame, but burns with invisible flame in and at the surface pores of the coke structure.

Hence a household fire of gas-works coke is a crude form of gas producer, with the advantage over the coal fire of being smokeless, less wasteful of coal, and more prolific in its useful yield of glowing radiant heat into the room. However, in spite of its technical advantage over the domestic coal fire, the open household fire of gas-works coke lacks popularity.

Low-Temperature Coke in the Domestic Open Grate.

Expressing this in terms of a gas engineer: The temperature of manufacture of low-temperature coke, relatively to gas-works coke, is lowered to 600° C. (1110° Fahr.) from 1000° C. (1830° Fahr.), as a direct consequence of which gas is liberated from the low-temperature coke structure in the open domestic grate at 600° C. (1110° Fahr.). Thus the open domestic grate can better maintain its fire of cheerful appearance, although it only contains a mere handful of low-temperature coke. Thus is the cheer of the coal-fire coupled, or allied to, the technical merits of the coke fire.

Ash Content in All Types of Coke.

Gas-works, in their laudable and praiseworthy efforts to produce and maintain as of prime importance cheap gas, buy cheaper and consequently inferior coals, containing various and relatively high percentages of ash, which in the nature of things is concentrated, as an increased percentage of ash, in the resulting coke or coal residue. When coal containing a high percentage of ash is burned in the domestic grate, the ash has a less deleterious effect upon the coal fire than the same percentage of ash would have in a coke fire in the domestic grate.

This is due to the fact that coke burns as a surface combustion in the cell structure of the coke surface; and if the ash be of sufficient quantity, it can easily act as an envelope, and mask so many cells, by preventing the oxygen of the atmosphere contacting with the real coke surface, that the small parcel of coke in the domestic grate is rendered pessimistically dull and unpopular. Thus it will be obvious that, for domestic use, more than for any other service, must the ash content of the coke be lowered to below (say) 5 p.ct., which entails the purchase of washed coals to a greater extent than hitherto.

Crackling of Coke when Consumed on the Domestic Open Grate.

Though some of the crackling sound may be due to stone in the ash of the original coal, gas-works coke, being almost always water-quenched, contains moisture in its interior; and it is the liberation of this moisture, as invisible steam, in minute quantities, which sets-up a noisy crackling liveliness that in the household is highly deprecated. Moreover, this crackling noise is accompanied by minute dust particles shot on to the hearth, rendering the fireplace untidy, so that the housewife (the Chancellor of the Exchequer on fuel purchase) is prejudiced against the use of coke.

Therefore dry quenching or smothering is a *sine quâ non* of a satisfactory production of domestic fuel, and ought to be adopted for the quenching of all coke, and where practicable the sensible heat thereby utilized with double advantage.

Washed Coals and Colliery Practice.

The erstwhile cheap coals of Britain, allied with the onerous spirit of the miners' trade combines, have hitherto had the effect of bringing to the pit-head chiefly the prime coals only, and of leaving millions of tons of slack and inferior coals in the pits. This practice has prevented to a large extent the true economic development of coal washeries at the pit-head. The present-day economic outlook of the British coal fields, coupled with the short working hours of the miners at the coal face, will now have the opposite tendency; and there is already a

desire to bring up the slacks and wash them so that more ready markets can be found. Thus will a gas-works steady and growing demand for a clean coal be met, without any burdensome on-cost to prevent development.

Low-Temperature Fuel versus Free-Burning Smokeless Fuel.

It is of the utmost significance to the future of the production of domestic fuel to recognize clearly what has come over the experimenters to cause this change in nomenclature. Twenty years ago, when experiments on low-temperature carbonization commenced, low temperatures of 500° C. (930° Fahr.) were used. During the last decade, temperatures of 800° C. (1470° Fahr.) are spoken of, and simultaneously the name has changed from low-temperature coke to free-burning smokeless fuel. This has been brought about by a slow realization, from the evidence of many workers, that the porosity, cell-structure, or relative thinness of the carbon walls of the cell-structure, plays a part in the free-burning properties of the coke, of perhaps more real importance than the very low temperature of carbonization. If this be so, then gas-works, when producing smokeless free-burning fuel (coke), will be able at the same time to drive-off and utilize more volatiles to the advantage of cheap gas, and thereby enhance the over-all efficiency to conserve coal and cheapen gas.

Fine Grinding of Coal.

Many experimenters have proved the real worth of the fine grinding of relatively clean coal, and the blending of such coals to produce the microscopic thin-walled cells and enhance the free-burning qualities of the smokeless fuel.

Admixture of Coke Breeze.

Similarly, pulverized breeze has successfully been blended with coal, thereby giving the effect of blended coals in a cheaper manner, and increasing the rate of heat penetration and speeding the rate of carbonization, to the increase of the efficiency of the process. In fact some gas-works blend 10 p.ct. of breeze with coal, and yet get (say) 10 p.ct. speedier carbonizing—*i.e.*, shorter period of charge.

Uniformity of Carbonization.

In low-temperature work, metal, having a coefficient of heat conductivity of some twenty times that of the coal under distillation, has freely been utilized in various ways—such as tubes, plates, worms, retorts, and liquid baths—to conduct the heat evenly and quickly into the mass of coal. The use of ordinary iron alone, however, would limit the temperature of carbonization to (say) 500° C. to 600° C. (930° Fahr. to 1100° Fahr.); but should gas-works take up this work as outlined hereafter, chrome steel, special cast iron, calorized steel, chromium alloys, or carborundum will give freedom to use any temperature, even up to the present-day gas-works practice of 1000° C. (1830° Fahr.) within the retort, if experiment proves and practice shows (as I believe it will) that the free-burning properties are not seriously sacrificed by the further distilling-out of the valuable and profit-yielding volatiles.

Compacting the Charge of Coal Previous to Carbonization.

The property of free burning appears to lie chiefly in the degree of its microscopic cells, and consequent thinness of the carbon walls, so that visible looseness or porosity of the coal charge while under carbonization is of no advantage, but, on the contrary, may be a serious disadvantage in the economy of working, and in deterioration of the more friable fuel by breeze formation during handling or transit. Consequently means have already been used to compact the coal by briquetting, ramming, and carbonizing in vertical retorts, which feature should be developed in the proposed scheme for gas-works use.

Quantity of Heat Required to Carbonize Coal.

Strange as it may seem on first acquaintance, no heat is absorbed to carbonize coal. All that is demanded is the small amount of heat to ignite and start the process of carbonization over a sufficient proportion of the volume of the coal being carbonized, and (given time) the coal undergoing distillation will generate sufficient heat to complete the process throughout the remainder of the mass. This fundamental truth has been known so long as to be almost forgotten; or, to state the fact another way, the race for economy, by speeding-up, during the last generation has almost obliterated the knowledge from modern development. Yet one has only to conjure up in the mind's eye the old bee-hive coke oven, or the hay-box cookery, to assure one's self of this basic truth.

Now this dormant factor, if properly realized and applied, can be utilized to advantage. For example: Seeing that it is only necessary to heat a sufficient proportion of the coal to the desired temperature, in order to start the process, it follows that if, in low-temperature carbonization, we apply this lesser temperature at many surfaces, of the coal mass, we shall, in spite of the low temperatures in use, speed the process precisely and in the same manner, as though we had applied the vastly higher temperature of gas-works and the present-day gas-works practice. Therefore to increase the surface application of heat it is necessary that the coal shall be treated in thin slabs or layers.

Modern Heat-Resisting Metals, and Porosity of Fuel.

Much knowledge has accumulated in recent years, in developing alloys, and mixtures of metals, to render metals and metal shapes proof against deterioration at high temperatures, and capable of withstanding high temperature without distortion of shape. Simultaneously, as previously described, continued experiment has shown that the particular coke structure is a factor of the free-burning properties of fuel, so that higher temperatures of carbonization, and consequently a lesser volatile content, are more permissible than hitherto thought to be the case. Obviously experimenters in low-temperature carbonization have in the past been unaware of these two important factors.

A full realization of their correlated significance is to have the self-assurance that high-temperature carbonization and low-temperature carbonization are (judged alone by the average heat treatment of the coal-substance) developing towards a remarkable sameness. Therefore the *raison d'etre* of this paper is to apply this knowledge first and foremost in the interests of established gas-works, rather than that it should be realized and applied outside the gas industry and spent to waste in fruitless attrition.

Having reviewed the salient factors bearing on both technical and commercial success, I will enunciate the proposal for improved coke production in gas-works, or the production of free-burning smokeless fuel economically in existing gas-works retorts.

Smokeless Fuel Production in Gas-Works.

Accordingly, it is seriously proposed that portable retorts of iron, alloy, or carborundum be provided, each capable of withstanding 800° C. (1430° Fahr.) in development up to 1000° C. (1830° Fahr.). These retorts (of such size as to go within existing gas-works retorts) are to be divided into many narrow compartments, by cross webs or stiffeners. These webs serve to conduct the heat rapidly into, and ignite the mass of, the prepared coal (the conductivity of metal being about twenty times that of coal under distillation, and the coal mass being split into narrow slabs 2½ or 3 in. thick), so that the mass is speedily carbonized to uniform extent and with the minimum degradation of the oily vapours while leaving the retort. Stoking machines would be provided to traverse the retort house, and bodily and economically handle these metal retorts to and from the existing gas-works retorts (or exactly as many of the gas retorts as can deal with the particular demand for domestic fuel), now regulated as found best to 800° C. (1470° Fahr.) to 1000° C. (1830° Fahr.) on the inside walls.

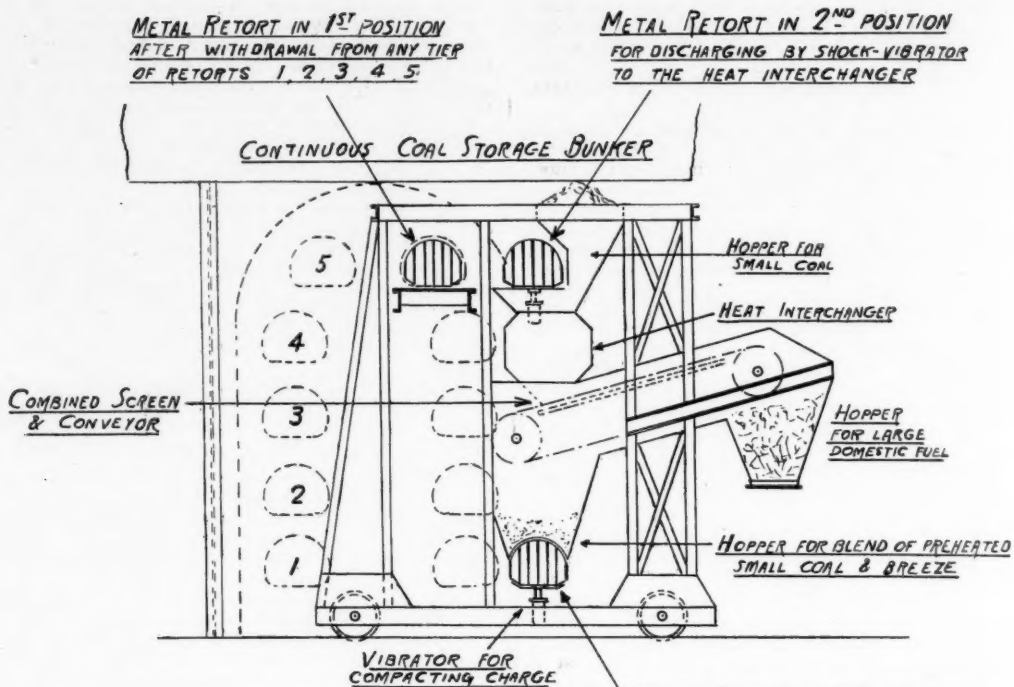
It should be noted as of importance that a distortion of shape over a considerable degree due to heat and usage will in nowise impede the satisfactory working of these retorts. These machines will be provided with means to dry quench, or smother, the discharged domestic free-burning smokeless fuel (coke), and may be fitted so as to regenerate the sensible heat of the coke by thoroughly drying and pre-heating the incoming pulverized or small coal for the following charges in known and proved manner. Alternatively, the machine may discharge the hot fuel into hoppers so that this exchange of heat may be carried out at greater leisure in apparatus separate from the stoking machinery; or the sensible heat of the discharged fuel may be used for steam raising, and the ingoing coal being charged may be pre-heated by the recently discharged hot iron retort or receptacle, as has been practised in conveyor types of low-temperature experiments. To compact the coal previous to charging, the metal retort is vibrated at (say) 1500 shocks per minute, as the pulverized and preferably dried or pre-heated coal is fed into same, in known manner, and as used in packing tea; or the coal may be rammed or stamped into position so that a very compact charge of coal is built without the cost of briquetting.

The scheme proposed is clearly set forth on the illustrations herewith, which are at once self-explanatory and obviously practical. Thus, if the provision of a smokeless free-burning domestic fuel be a national need, then this new method of coke production at any desired temperature turns to the common weal, and utilizes intact, without alteration, as a working whole, or in part, according to the dictates of efficiency, the hundreds of millions of pounds worth of plant and machinery now constituting the 800 gas-works throughout the country. That is to say, the existing retort benches, with all mountings, the hydraulic mains, the governors and foul mains, condensers, wet and dry purification plants, the gasholders, distributing services, and the complete organization of gas-works, would be available for producing:

(1) Free-burning smokeless fuel of quantity in direct proportion to economic demand;
(2) Or (by again raising the temperatures) ordinary gas-works coke and high-temperature gas, precisely as at present.

Moreover, the fuel thus produced in each gas-works district would be where and when required, thus economizing handling costs and on-costs of sale, to the advantage of maximum or national efficiencies.

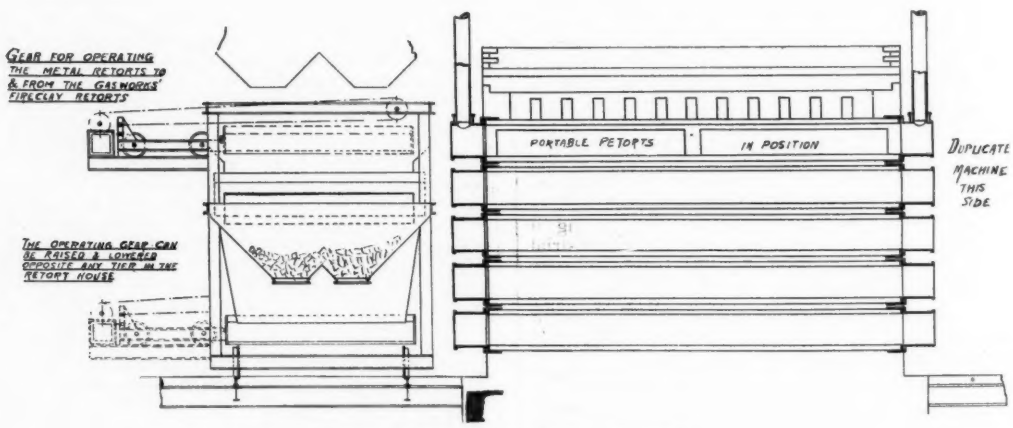
Consider such a plant already installed in one of our gas-works; the gas engineer desiring at the outset 20 p.ct. of his coke sales to be for the domestic market. Then 10 p.ct. only of his existing carbonizing plant would be reduced in temperature to 800° C. (1470° Fahr.) on the inside of the retorts; and the new stoking machine would manipulate the iron retorts in and out of these existing firebrick retorts. Such, however, is


METAL RETORT IN 1ST POSITION AFTER WITHDRAWAL FROM ANY TIER OF RETORTS 1, 2, 3, 4, 5
METAL RETORT IN 2ND POSITION FOR DISCHARGING BY SHOCK-VIBRATOR TO THE HEAT INTERCHANGER
CONTINUOUS COAL STORAGE BUNKER
HOPPER FOR SMALL COAL
HEAT INTERCHANGER
COMBINED SCREEN & CONVEYOR
HOPPER FOR LARGE DOMESTIC FUEL
HOPPER FOR BLEND OF PREHEATED SMALL COAL & BREEZE
VIBRATOR FOR COMPACTING CHARGE
METAL RETORT IN 3RD POSITION FOR BEING CHARGED COMPACTLY WITH COAL
5
4
3
2
1

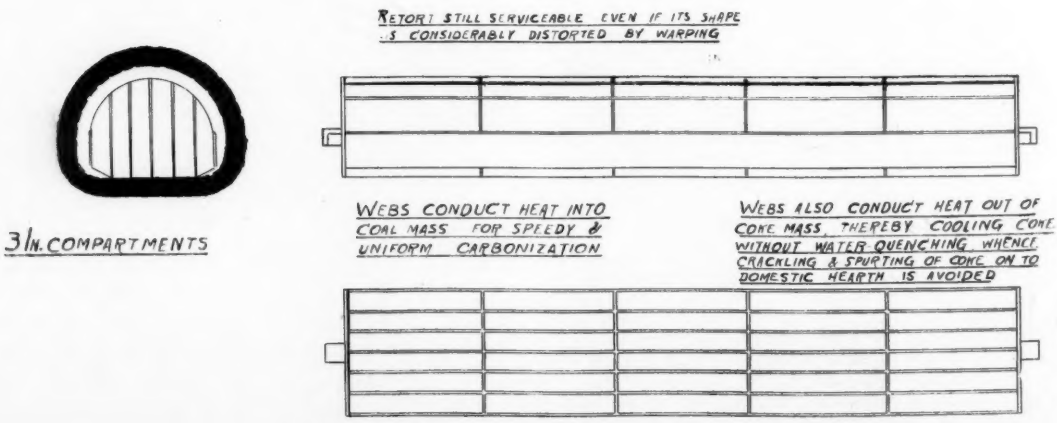
MACHINE STOKER

FOR

1.—Withdrawing the portable retorts from gas-works retorts.
2.—Discharging the domestic fuel from the metal retort.
3.—Blending slack coal with the freshly-discharged domestic fuel for
(*a*) Heat interchange.
(*b*) Utilizing and blending breeze with new charge.
4.—Screening the domestic fuel.
5.—Storing large domestic fuel in hoppers.
6.—Charging the blend of preheated small coal and breeze to the hot metal retort.
7.—Compacting the small coal during charging.
8.—Replacing the charged metal and hot retort into the gas-works firebrick retort.


GEAR FOR OPERATING THE METAL RETORTS TO & FROM THE GASWORKS' FIRECLAY RETORTS
THE OPERATING GEAR CAN BE RAISED & LOWERED OPPOSITE ANY TIER IN THE RETORT HOUSE
PORTABLE RETORTS IN POSITION
DUPLICATE MACHINE THIS SIDE

SIDE VIEW OF MACHINE STOKER.


RETORT STILL SERVICEABLE EVEN IF ITS SHAPE IS CONSIDERABLY DISTORTED BY WARPING
3 IN. COMPARTMENTS
WEBS CONDUCT HEAT INTO COAL MASS FOR SPEEDY & UNIFORM CARBONIZATION
WEBS ALSO CONDUCT HEAT OUT OF COKE MASS, THEREBY COOLING COKE WITHOUT WATER QUENCHING WHENCE CRACKLING & SPURTING OF COKE ON TO DOMESTIC HEARTH IS AVOIDED

PORTABLE HEAT-RESISTING METAL RETORTS.

the obvious capacity (proved by several low-temperature experiments) of the iron embedded in the coal mass, that a period of six hours will readily suffice to perform what at present requires twelve hours. *En passant,* it may be noted that the firebrick retort can now be virtually filled with coal, thereby increasing economies, and speeding exit of valuable vapours.

The richer low-temperature gas of less volume—say, 35 therms per ton of coal carbonized at low temperature—will make-up the thermal yield of gas from each gas-works retort, for example:

High temperature—
68 therms per ton of coal.
35 cwt. of coal per through retort per diem.
120 gaseous therms yield per retort per diem.

Low temperature—
35 therms per ton of coal.
70 cwt. of coal per through retort per diem.
120 gaseous therms yield per retort per diem.

The relative coke yield per retort per day will be:

High temperature—
25 cwt. of coke.

Low temperature—
50 cwt. of coke.

Allowing for the fuel used on producers, the surplus coke and breeze leaving the bench for disposal will be:

High temperature practice—
20 cwt. coke per retort per day = 11 cwt. per ton of coal.

Low temperature proposal—
45 cwt. coke per retort per day = 12½ cwt. per ton of coal.

This represents an increase, in favour of the new proposal, of 125 p.ct. per retort and 13½ p.ct. per ton of coal, which increase is the more important seeing that the revenue on coke is acknowledged to be the prime factor in reducing net cost of coal—the essential factor of gas-works economy.

By constructive reasoning, we have therefore arrived at the very desirable, if startling, evidence that the adoption of this proposal will permit existing gas-works to:

Maintain its thermal yields of gas for the town's requirements.

Increase by 100 p.ct. the coal throughput, or turn-over from existing plant.

Increase by 125 p.ct. the surplus coke and breeze for disposal.

Increase by 150 p.ct. the tar for sale or for dehydration for motor roads, &c., and for distilling for the manifold and complex uses of modern industry.

Increase by 10 p.ct. its ammonia yield to the advantage of agriculture.

And thereby enable gas-works (to the extent of the economic increase of coal throughput equal to 20,000,000 tons per annum) to convert the present colossal national smoke-wastages to account, and fortify the national revenue in the best of all ways by increasing nature's sunshine and balm, and by reducing the wear and tear of human life and property.

As an exemplification: Assume one of our enterprising seaside resorts, proud of its pure and bracing air, decides to prevent, by economic means and precept, the pollution of its atmosphere by smoke from domestic chimneys. Being a seaside town, far removed from the coalfields and industrial centres, coal will be relatively dear, and the natural coke market chiefly domestic.

Therefore as a basis:

Household coal, 45s. per ton.
Gas-works coal, 22s. per ton.
Return on residuals as a percentage of coal, 72 p.ct. with the present good gas-works practice.
Return on residuals as a percentage of coal, 80 p.ct. with the proposed production of free-burning smokeless fuel, if sold at the same price as gas-works coke.

—	High Temperature (existing).	Low Temperature (new).
Coke burned as fuel on retort settings per 100 lbs. of coal carbonized	14 lbs.	7 lbs.
Ditto. per ton of coal carbonized	3 cwt.	1½ cwt.
Coke and breeze leaving retort bench for disposal	11 cwt.	12½ cwt.

Return on Residuals per Ton of Coal Carbonized.

	High Temperature.			Low Temperature.		
	P.Ct. of Coal.		s.	P.Ct. of Coal.		s.
Coke and breeze	55	=	12·1	63	=	13·8
Tar	10	=	2·2	12	=	2·6
Ammonia	7	=	1·5	5	=	1·1
Total return	72	=	15·8	80	=	17·5
Net cost of coal	28	=	6·2	20	=	4·5

Thus economic advantage accrues, even if the free-burning fuel be sold at gas-works coke prices; but to arrive at the ideal, and divide the advantages gained between the users of both gaseous and solid (smokeless) gas-works fuels—that is, gas into holder at 0·0d. per therm, or net cost of coal 0·0d. per ton, the price at which domestic smokeless fuel could be sold would be 27 p.ct. above the present price of gas-works coke, all other factors being equal. That is to say, in our supposed seaside example, free-burning smokeless fuel could be produced and sold in conjunction with gas at rock bottom cheap price at 33s. per ton, equal to three-quarters or 75 p.ct. the price of household coal.

To summarize, this proposed improved production of free-burning smokeless fuel offers:

(1) An immediate and profitable solution of the problem of smoke prevention.
(2) A process that can be tried-out *ad lib.* on existing plants.
(3) An immediate application to all towns, and exactly controllable to economic demand
(4) All at the very minimum of capital cost, without risk, as plants can as often as required revert to present-day practice, or high-temperature bulk carbonization and gas-works coke.
(5) An unlimited coke market in each gas-works' own district, so that while each gas-works works out its own economic destiny by its sales department, costs, losses, and deterioration of coke during transit are eliminated.
(6) A radiantly hot household fire, free from soot and smoke.
(7) A healthy and hygienic atmosphere in Britain's homes and industrial centres.
(8) A practical method of improving present-day gas-works coke by blending a percentage of free-burning fuel with same.
(9) A conservation of our national heritage—British coal.
(10) An increase in the efficiency of use of the coal so treated.
(11) A reclaiming of the tar and ammonia for the use of trade, which is now lost via the domestic chimney to vitiate our atmosphere and deteriorate our buildings.
(12) A saving of millions of money, that will be spent in continued experiments outside the gas industry, and also preventing needless over-lapping of interest in time to come.
(13) A possible doubling of the coal throughput and residuals of existing gas-works, without appreciably increasing capital outlay.
(14) A national service, and possible nucleus of a great export trade in manufactured smokeless fuel and allied residuals from the 100,000,000 tons of raw coal now wantonly burned annually in household grates, industrial boiler furnaces, and for the generation of electricity.

Conclusion.

To conclude, it has oft been said within the gas industry: "Given the demand for domestic low-temperature coke, we can produce it." Can we (of the gas industry), first as citizens, and secondly as engineers (rightly proud of the past achievements of our industry), peacefully rest wrapped in self-satisfaction, while all around us is the din of earnest straining to create that demand, by the only way acknowledged or known to the world of industry, "producing samples"?

Domestic chimneys in their millions belch forth destruction to life, health, wealth, and happiness, and tarnish all nature with gloomy pessimistic foreboding. The sulphurous smoke pall, so prone to kill in time of war, is therefore turned against man's every laudable effort in time of peace. Who then, having driven the Smoke Fiend from his lair, the London fog, with their first arrow, the gas-fire, are more fitted to spur themselves for mortal combat to slay the Demon Smoke with a second arrow from their quiver, their secondary product (coal residue), coke, than is our gas industry?

This paper, in popular parlance, is written with the minimum of technical jargon, and is the outcome of extended observation, some early and late experiences with low-temperature carbonization, and, with constructive criticism, by one who has been over twenty years a carbonizer. It summarizes considerable data, directs a way, and points the period for action, while always maintaining in the vision of the mind, those immortal words of wisdom:

"There is a tide in the affairs of men
Which taken at the flood leads on to fortune.
Omitted, all the voyage of life
Is bounded in shallows and in miseries."

In fine:

The propaganda for such a fuel has done its work.

The public demand exists.

The steel to withstand 1000° C. is available, *i.e.*, South Met. calorized steel.

The costly briquetting has been obviated.

The economic condition of the coal trade is facilitating the future marketing of washed slacks.

The psychological moment is here.

The existing gas-works plant can function *ad lib.*; hence economies are on the side of gas-works.

The records of the past direct that the production of smokeless free-burning fuel should be incorporated within the gas industry.

Then, if not, why not?

APPENDIX.

The writer, after completion of the foregoing paper, is pleased to observe such close corroboration of ideas expressed at the recent meeting of gas engineers. To facilitate the subject-matter of this paper being read in conjunction with this trend of advanced thought on the coke question, the following extracts from the Technical Press, on the recent June meeting of the Institution of Gas Engineers are appended:

"It is impossible to exaggerate the importance of doing everything that is possible towards the better utilization of our coal supplies."

"The baneful effect of smoke is evident in the drab and sordid appearance of many of our towns, and also in the reduction of sunlight and ultra-violet rays, which adversely affects health, and involves expenditure in maintenance of buildings."

"The time has arrived when the use of smoky fuel should be prohibited by legislation, in the interests of health, and to conserve our coal supplies."

"Hence, low-temperature carbonization is attractive. It has not, however, so far been established by independent data to be on a stable financial basis."

"The seriousness of the coke position throughout the industry calls for united action, with a view to promoting an increase in its use for industrial as well as for domestic purposes."

"We have reached a state of knowledge at which it may be said that with present plant and materials we are getting approximately maximum results."

"The duty of the gas industry is to make the maximum use of potentialities by insistent, persevering research, and by the application of the findings as we proceed, and as opportunity serves."

"With regard to a modified gas-works grade of coke made in coke ovens, gas-works have the advantage of local situation, and better distribution facilities, and it is a question of adding to that a proper preparation of coke and improving the quality as far as possible, with the view of making it preferable in the region of its production."

"The Gas Investigation Committee, it was suggested in the Technical Press, should undertake a thorough research into coke production."

"There is much need for precise information as to the physical qualities of coke which, without sacrificing our high-temperatures in carbonization, will give good ignition and combustible values to the product."

"There is also the question of mixing a proportion of coke with the coal charges, and the definite ascertainment of the effect this would have upon the transmission of heat through the charge, upon the throughput and productivity of the retort, and upon the ability to use lower temperatures, with advantage to the life of the refractory material, as, if we can get a carbonizing plant to have a longer life, the costs of carbonization will be reduced considerably. This will materially affect the lower net cost of gas."

In conclusion, the Appendix certainly emphasizes the subject-matter of the paper as designated "Gas-Works' Opportunity."

SECTION I.—COKE PRODUCTION.—(*Continued*).

Fourth Award, won by "Thesaurus."

BY DR. W. B. DAVIDSON, OF TYNEMOUTH.

1. Demand for Coke, and Qualities Required.

It is necessary at the outset to get, as it were, a bird's-eye view of the coke situation, before we can attempt to find the weak spots in the field of operations, or persuade readers that the proposed solutions of the problem are worthy of serious consideration. I therefore set out by enumerating some of the principal sources of demand for coke, describing very briefly the respective characteristics required.

Steel manufacture and other metallurgical processes require large, dense, hard coke with an ash content of less than 12 p.ct., a sulphur content of not more than 1 p.ct., and moisture less than 3 p.ct. It is only in exceptional cases that gas undertakings are able to supply coke complying with this specification. The supply is drawn mainly from beehive ovens and coke ovens. Coke is essential because coal becomes more or less plastic, and cannot support the weight of ore or metal, and gives-off volatile matter and smoke, which constitute waste and nuisance.

Smiths' forges, on the other hand, require small coke nuts, or usually 1 in. washed breeze. The "sinkers" in the latter case have to be disposed of at a low price necessitating a higher price for the "floatings." Smithy coke causes trouble if it is high in ash of low-fusion point, which renders welding more difficult. High sulphur content is also detrimental. Non-caking coal nuts or peas of low ash and volatile content form the alternative to screened coke breeze.

For a great variety of purposes, such as external heating without direct contact of fuel and material, as in bakers' ovens, metal melting, muffles, also central heating by slow combustion stoves, &c., fairly large, moderately dense coke is in best demand.

For water gas manufacture a suitable coke is one varying from about 1 in. to 3 in. in size, though naturally the best results are obtained where there is greater uniformity—say, 2 to 3 in. When the ash is high and of low fusibility, the labour of clinkering the generators is much increased; the brickwork suffers greater damage, and the total costs of water gas production go up. Any dust or very small coke charged into the generators tends to be lost by getting blown over by the steam or air blast.

In processes of complete gasification used by gas undertakings, the whole of the coal is converted into gas; the coal being gasified either in one stage continuously without handling any coke made by retorting, or in two stages by discharging the red-hot coke into generators which form an intimate adjunct of the carbonizing plant. In this case no coke is made. In one type of complete gasification plant, the design permits of the withdrawal of some coke in order to avoid reducing the quality of the gas to a very low degree. Such coke must necessarily be small in size and very high in ash content, and therefore cannot find a ready sale. It can, however, be used on the works boiler plant.

External gas producers are able to gasify very small coke, but are hardly capable of dealing satisfactorily with coke dust (through $\frac{3}{8}$ in.) alone; air and steam blast being greatly impeded by a deep stratum of material of this small size—blow-holes resulting. There is no difficulty, however, in working external producers, mechanical or water-luted, with mixed small coke and dust, or what is generally termed "unscreened breeze," so long as the ash is not of too fusible a nature. Mechanical producers, such as those of the Kerpely type, are known to work satisfactorily on fuel containing as much as 40 p.ct. of ash. It is generally found impracticable to feed small or dusty coke to internal producers, though, of course, it is common practice to fire them with red-hot coke coming directly from the retorts, before it is subjected to breakage by quenching and special handling. For external gas producers non-caking coal (nuts by choice) is preferred, but on a gas-works the gasification of unscreened coke breeze is a great economy.

Boilers of either water-tube or Lancashire type are fortunately able to burn any kind of coke, provided the grates are suitable, and fitted with forced draught. The results are distinctly better, however, if the coke is of medium size; the duty and thermal efficiency being both improved. When, therefore, boilers are to be fired with coke dust only, provision must be made for increasing the plant above that normally required, perhaps to the extent of 30 p.ct. Another difficulty to be confronted is the entrainment by the flue gases of fine coke dust and ash particles which collect at bends in the flues, and tend to cause blockages and constrict the gas ways leading to the chimney-stack, thereby increasing the gas velocity to a point at which nuisance ensues by dust carried out of the chimney.

In the large power stations, low-priced "rough small" coal containing as much as 25 p.ct. of ash is used successfully to feed the mechanical stokers of water-tube boilers, which give a total thermal efficiency of over 80 p.ct. and a duty that would, perhaps, not be possible with coke. The advantage of the consumption of coke by boilers is therefore restricted mainly to gas-works, and consists essentially in the economy of utilizing coke-dust which might otherwise have to be carted to tip.

For the other manifold purposes for which gas coke is sold, the general requirements are those that apply to solid fuel of all kinds:

The coke should be as dry as possible.
It should have a low cost per therm.
It should make as little ash as possible.
It should not be too difficult to ignite.
It should not be too friable.

In special cases certain exceptional requirements are stipulated before coke can be used. Thus, for malting barley, the almost entire absence of arsenic is necessary. For the manufacture of calcium carbide in Scandinavia the presence of phosphorus has to be avoided as far as possible in the coke

imported. Scandinavians also pay particular attention to the fusibility of the ash in the coke they obtain from the North-East coast, as they object to having too much clinkering trouble in their central heating stoves.

Of paramount importance, in the writer's opinion, is the home demand for coke for household purposes—that is, for the kitchen fire, which may be open or closed, for the closed slow combustion stove for water heating, and most of all for the open fire of the dwelling-room. With nearly 20 years' personal experience in the utilization of coke in open fires, to the exclusion of coal, in five different houses and, perhaps, twenty different grates, I am convinced that the household demand for gas coke can be so stimulated as to be capable of absorbing the whole of the present supply of gas coke, and a great deal more.

The consumption of coal for domestic use in Great Britain in the year 1922 is estimated by the Board of Trade at 38,000,000 tons, while gas-works used 16,500,000 tons which made approximately 8,500,000 tons of coke for sale.

The household coke demanded by those who know what is best should have the following characteristics:

The size should be ¾ in. to 1¾ in., preferably 1 in. to 1½ in.
It should be ignitible without difficulty.
It should be as dry as possible, moisture not to exceed 4 p.ct.
It should have an ash content as low as possible; this ought not to exceed 10 p.ct.

Householders who are ardent smoke prohibitionists or who have special objections to the use of raw coal will, of course, continue to use gas coke, and shut their eyes to the shortcomings of this fuel. We are now, however, considering the cause of the small demand ruling at the present time.

II. Supply of Coke.

Let us look at the available supplies of coke.

1. *Beehive Coke* made from beehive ovens without recovery of gas, tar, benzole, or ammonia commands the higher price, and is used for foundry and other metallurgical purposes. As far as can be ascertained, however, it is not superior to coke oven ("patent") coke, though it generally looks more silvery and is somewhat denser. Beehive ovens entirely disappeared in Germany ten years ago or more, and are rapidly giving entire place to coke ovens in this country, probably now supply not more than 10 p.ct. of the total requirements of metallurgical coke.

2. *The British Coke-Oven Industry* (including beehive ovens) used 13,300,000 tons of coal in the year 1922; and on a basis of 75 p.ct. yield (coke oven gas being used as fuel for heating the ovens) the coke produced was about 10,000,000 tons. Five per cent. or so of this coke forms, by breakage, coke-nuts and coke-breeze, and is partly used up on the coke oven works for steam-raising, or is sold for domestic and other uses.

The price obtained for patent coke depends almost entirely on the state of the steel and engineering trades. At present these industries are exceedingly flat, and coke prices are at a very low ebb. On an average, coke-oven coke probably fetches a higher price than gas coke, and at one time it appeared a sound commercial proposition to instal coke-ovens in gas-works, heating the ovens with producer gas regeneratively, and retaining all the coke made for special sale as metallurgical coke. This has, however, only been done at one gas-works in this country—namely, Saltley, Birmingham.

By the choice of suitable Yorkshire coal, disintegrating and stamping the charges, patent coke of a quality quite suitable for metallurgical purposes is made and sold; but, with the low prices that have been ruling during the past year or two, coke ovens for gas-works are not particularly attractive. It must also be borne in mind that it is not every large town that has a sufficient demand for furnace coke, that a coke oven installation is more costly than one of horizontal or vertical retorts, and that coke ovens do not lend themselves very well to the steaming process used for lowering the grade of the gas made, and thereby reducing the cost of the gas therm.

It might be thought that, by the selection of coal of moderate caking strength and the use of unstamped charges, a soft, though very large, coke could be produced which could be sold readily, when broken to a proper size, as suitable for household and general purposes. The proportion of coke breeze and dust made in the operation of breaking this very large coke is probably, in addition to the other disadvantages already mentioned, too heavy a handicap to warrant the risk of installing coke oven plant with the idea of catering alternatively for two totally dissimilar demands varying with the industrial times.

3. Gas Undertakings.

(*a*) *Coke Ovens and Chamber Ovens.*—As already mentioned, these installations are exceptional, and for the reasons stated not calculated to prove generally so profitable as ordinary retorting. Of all carbonizing plant, the coke they produce is the largest, hardest, and densest, and least suitable for supplying what the writer regards as the most important demand—that of a smokeless fuel for general household use.

(*b*) *Intermittent Vertical Retorts* come next to ovens in the size and density of the coke made. Dessau retorts have a special advantage in reconverting into large coke a considerable proportion of the small coke breeze usually made from horizontal or continuous vertical retorts; and the coke when properly handled—by telpher, for example—forms a comparatively small amount of breeze. This breeze is returned into the bottom of the retort before charging with coal. The tar running down from the coal being distilled is soaked-up by the breeze, and the mixture slowly forms large coke.

(*c*) *Horizontal Retorts with Large Charges* produce nearly as large coke as do intermittent vertical retorts, but the density is less, owing to the smaller superincumbent weight in the retort during the period of plasticity.

(*d*) *Horizontal Retorts Charged with Light Charges* produce smaller, softer coke which burns more readily in an open fire than that made from full charges. In general appearance, however, it is not so good.

(*e*) *Inclined Retorts* can usually be manipulated only with light charges.

It is noteworthy that, whereas ovens and intermittent vertical retorts can only be discharged after the coal has been distilled practically to a finish—that is, after the charge has lost its plasticity and undergone contraction—the coke can be pushed from horizontal retorts in a semi-carbonized state.

It is a fault with all the above systems that the red-hot coke has to be quenched. The usual methods of quenching with water leave a good deal to be desired, as it is a difficult matter so to regulate the amount of water used as to produce coke that is sufficiently dry—that is, containing (say) less than 4 p.ct. of water. This is achieved best in the case of ovens by the well-known Darby quencher, followed by other devices such as the sloping bench, the Goodall rotary quencher, or the railway telpher—the last-named travelling quickly to the base of a ferro-concrete tower for final quenching and steam removal.

(*f*) *Continuous Vertical Retorts*, if properly managed, provide coke containing less than 1 p.ct. of moisture. The coke is equal in size to that obtained from horizontal retorts with moderate charges. It is comparatively light and porous, and if not too completely deprived of its volatile content by severe steaming is admirably suited for house fires, as well as for general purposes.

(*g*) *Low-Temperature Carbonization* processes for the most part aim at supplying a smokeless house fuel *par excellence*. The plant worked by Low-Temperature Carbonisation Ltd., at Barugh, Barnsley, carbonizes 100 tons of coal per day for the purpose of making "Coalite." The coal contains only 4 to 5 p.ct. of ash, and costs 25s. per ton. The coke has an ash content of 6 to 7 p.ct., and is said to be sold at 42s. per ton. This plant does not supply to gas-works the rich gas made in the process, but it is said that the Company have made a contract with the Nottingham gas undertaking for a plant dealing with 1000 tons of coal per day, the gas from which, after debenzolizing, will be mixed with lower-grade coal gas for town supply. (Since writing we learn that this project has not materialized.)

The coke is nearly black, fairly dense, and contains 5 to 10 p.ct. of volatile matter. It is easily ignited as compared with gas coke, and emits considerable flame.

The Maclaurin process of low-temperature carbonization is now in the initial stages of its commercial trial by the Glasgow Corporation at their Dalmarnock Gas-Works. This consists of a five-unit battery (20 tons per unit) carbonizing 100 tons of coal per diem. It is claimed that this plant can produce from the same coal, as required, either smokeless fuel or hard metallurgical coke, or in emergency can completely gasify the coal, making no coke. The coal preferred is one of low caking strength.

III. Influence of Coal Character on Coke Nature.

1. The caking index of the coal foretells fairly accurately the kind of coke that will be manufactured. For example, those coals having an index of over 20 (Gray's standard) are excellent coking coals. Gas coals of high caking index of 20 or more are difficult to carbonize in continuous vertical retorts. Durham coals are the most strongly caking coals in this country, and do not require stamping for coke-ovens. Certain Yorkshire coals come next. Most gas coals have an index of 10 to 20. It is essential that they have some caking strength. An index of 12 to 15 is perhaps the most desirable.

2. Plasticity goes nearly hand in hand with caking index. High plasticity sets-up pressure in vertical retorts, and interferes greatly with discharge, especially in vertical retorts worked at low temperature. Many caking coals thus find themselves outside the sphere of low-temperature carbonization.

3. Volatile matter content settles, generally speaking, the case of ignition both of coal and coke. A certain minimum content (about 27 p.ct.) is necessary if the coal is to be of comparatively good value for gas-making. High oxygen content of the coal detracts from the value of the volatile matter, seeing that on distillation it goes chiefly to form water; so that the percentage of volatile matter alone is not an accurate criterion of gas-making quality. The percentage of available hydrogen—that is, the hydrogen percentage less one-eighth of the oxygen percentage—is a good guide. This should exceed 4 p.ct. in gas coals. It will be noted that the higher the volatile matter in the coal, the less will be the quantity of coke made, though, as a rule, the gas yield (also tar yield) will be improved.

4. Moisture in the coal being also volatile, though not included in what is known as "volatile matter," will reduce the

percentage coke yield. It also, of course, reduces the value of the coal *pro rata*. Many younger coals such as those of Derbyshire and Northumberland are naturally high in inherent moisture—that is to say, they contain a comparatively large percentage of moisture (as much as 8 p.ct.) without being wet. Other coals again may be moist, as they come from wet places in the mine, while washed nuts and peas may be very wet (up to 10 p.ct. moisture) as delivered fresh from the coal-washing plant.

When both moisture and volatile matter are high in content, the yield of coke is necessarily low, assuming ash to be constant. Thus a coal with 8 p.ct. of moisture and 37 p.ct. of volatile matter will give a total coke yield of only 55 p.ct.

Best Durham gas coals with moisture of 1½ p.ct. and volatile matter of 33½ p.ct. give a yield of 65 p.ct. of dry coke, while coking coals containing 25½ p.ct. of volatile matter give a dry coke yield of 73 p.ct., some even going as high as 80 p.ct. of coke as quenched.

5. The ash present in the coal—or, one should rather say, the ash remaining after the combustion of the coal—is a non-volatile constituent like the "fixed carbon," and in conjunction with the latter forms the coke. With one and the same coal substance, an increase in the ash content reduces the percentage content of moisture, volatile matter, and fixed carbon *pro rata*, but increases the percentage yield of coke. Needless to say, the ash in the coke is increased; the percentage increase being practically equal to that of the ash in the coal. An example will serve to show the effect:

—	Normal Coal.	Same Coal Substance with 50 P.Ct. More Ash.
Moisture, p.ct.	2	1·91
Volatile matter, ,,	33	31·57
Fixed carbon, ,,	57	54·52
Ash, ,,	8	12·00 (50 p.ct. increase)
	100	100·00
Coke, ,,	65	66·52
Ash in coke, ,,	12·31	18·04 (46·4 p.ct. increase)

It may be remarked here that laboratory tests of volatile matter (hence coke yield) carried out by the standard method agree reasonably well with the works results when allowance is made for moisture.

Considered in a simpler way, the numerical relation of ash in the coal to ash in the coke may be taken to be, on an average, 2:3 (moisture + volatile matter = 33·3 p.ct.). The following table of ash percentages indicates the ash content of bulk deliveries of different coals and cokes:

—	1 Best.	2 Good.	3 Fairly Good.	4 Rather Bad.	5 Bad.	6 Very Bad.
Ash in coal, p.ct.	4	6	8	10	12	14
Ash in coke (dry) ,,	6	9	12	15	18	21
Ash requiring handling	100	150	200	250	300	350

There are two points of view with regard to the ash. The gas engineer is inclined to look upon Class 5 coal as simply 8 p.ct. inferior to Class 1, because calculation and tests show that calorific value and gas yield are so much less. The fireman and coke consumer, on the other hand, find that the ash to be removed is trebled, and assesses the difference between the two at something much more than 8 p.ct. The fact that there is a definite limit to the ash in coke that can be practically fired (a limit of perhaps 30 or 35 p.ct.) also tends to prove that the real difference is much greater than the former estimate.

6. Calorific Value.—Whereas moisture and ash in all coals and cokes have, of course, the effect of lowering the calorific value, this effect is not so regular or definite in coal as it is in coke. In the former the nature of the volatile matter has an important influence, depending on whether it is slightly or greatly oxidized—in other words, on the oxygen content. For example, young coals approaching the lignite type, high in volatile content but also high in oxygen, have a calorific value, calculated on a moisture and ash-free basis, of only 13,500 to 14,500 (carbon being 14,600); whereas high-class gas coals have calorific values, reckoned on the same basis, of 15,200 to 15,700.

Gas coke, on the other hand, containing, as it does, a very small amount of volatile matter, admits of ready and fairly accurate assessment for calorific value by assuming the coke to consist simply of carbon, ash, and moisture. The net value is only about 1 p.ct. less than the gross value.

IV. Coke *versus* Coal.

1. *Advantages of Coke.*—Coke has certain definite advantages over coal, and it is our business to look into these and ascertain how they can be strengthened.

(*a*) Cleanliness.—Coal dust is a great nuisance. Coke, on the other hand, is clean to handle.

(*b*) Smokelessness.—The great virtue of coke is its smokelessness when burning. The evils and waste resulting from the production of smoke from both house and factory chimneys have been investigated and published. They should be well known by this time to the good citizen, who ought to take the lesson to heart. It is difficult to understand the general lack of endeavour to use smokeless fuel. With regard to large electric power stations possessing boilers fitted with mechanical stokers, not much complaint can be raised on account of smoke, which mainly arises when there is a sudden drop in load. Most other factory chimneys, and particularly colliery chimneys, are great sinners with respect to smoke nuisance. The Nicol "Sandwich" system (coal on top, coke below) helps greatly to eliminate smoke, but the use of coke in this case will naturally depend on the price per therm; and I believe it is only in exceptional cases that unscreened small coal is not considerably cheaper for boiler purposes.

Briquettes made from coke dust and pitch (about 6 p.ct.), though easy of ignition, can hardly be pronounced a great success, partly because they do make a good deal of smoke, and partly on account of the high ash content, which is much higher in the dust than in the coke.

(*c*) In storage of coke there is no loss of calorific value as there is in the case of coal. On the other hand, there may arise serious losses by handling or crushing when a large stack has to be made.

(*d*) In radiant efficiency coke excels in comparison with coal. For this reason less solid therms—if we may use the term—are required to heat a room by an open fire with coke than with coal. The thermal efficiency of an open coal fire may be taken as not more than 20 p.ct., whereas that of coke is at least 25, and may be as high as 30. Dr. Margaret Fishenden gives a higher value for coalite than for gas coke; and it is difficult to account for this. In experiments I made a good many years ago on an open fire I could detect no difference in economy between coalite and gas coke. I am inclined to the opinion that the ash content has a good deal to do with the results, as a high ash militates against radiance, owing to the masking effect which it has.

(*e*) A higher temperature is to be obtained with coke than with coal in ordinary fires and furnaces. This is evidenced by the formation of clinker (fused ash), which is not an uncommon occurrence even in a kitchen fire using coke. Higher temperature is synonymous with greater radiation. When the fire is a closed one, there may be no economy in high intensity of heat. For example, in a closed kitchen fire (not open at the top) there is no difference in fuel consumption on a therm basis between coal and coke.

The formation of clinker may be regarded as a mixed evil. It serves to consolidate the ashes and make them less bulky and more convenient of removal to the tip. On the other hand, it interferes with the draught by stopping the air passages through the fire bars.

The higher temperature attainable is due partly to the removal of the volatile portion of the coal, and partly to the concentration of carbon, especially when the coke is dense.

(*f*) Economy of fuel is the result of the greater radiation effect of coke. This also results from the slower and more regular burning of the coke as compared with coal.

(*g*) Recovery of Oils.—It has for many years been held up as a standing disgrace to our country that so much raw coal is consumed without first recovering the tar oils and motor spirit. The gas undertakings and the coke-oven plants are the only cases in which bituminous coal is thus properly utilized, and they, combined, account for less than one-sixth of the coal consumed in Great Britain. The main object of the gas industry being to manufacture town gas, and that of the coke-oven industry to produce coke, it is not surprising that the recovery of tar oils is in neither case anything like so good as it might be if this were the main object. Fortunately, the production of the most suitable house coke can be accomplished simultaneously with the recovery of something like twice the yield of tar oils obtained in gas-works practice. This is the chief feature of low-temperature distillation. The maximum conversion of coal into oil is probably, however, not attained by any process of destructive distillation, but by other means of a more novel character such as hydrogenation under pressure.

2. *Disadvantages of Coke.*—We will briefly enumerate the main disadvantages of coke, and afterwards consider how these may be wholly or partially eliminated.

(*a*) The calorific value, as we have already seen, is less than in the corresponding gas coal. Taking, for example, a Durham gas coal containing 2 p.ct. of moisture and 8 p.ct. of ash, we may expect a calorific value of approximately 14,000. When converted into coke at the usual high temperature of carbonization, 2 p.ct. of moisture being afterwards added, the calorific value will be about 12,600—a drop of just 10 p.ct.

When a moderate amount of volatile matter is left in the coke, the loss in calorific value is not so great. Certain coals of high volatile and high oxygen content (and comparatively low calorific value) produce under low-temperature conditions coke of thermal value equal to that of the coals themselves. An extreme case is found in dry brown coal, which, on subjection to only slight destructive distillation, increases in calorific value by the elimination of the primary oxygenated products of decomposition—namely, carbon dioxide and water.

It must be pointed out that there is a great deal of uncer-

tainty—inaccuracy, one might say—in literature regarding the calorific value of coke. It is generally put down at much too low a figure (*e.g.*, "Gas Engineers' Compendium," 11,500 for coke of from 8 to 10 p.ct. ash, instead of 13,200). This no doubt arises from the difficulty of burning the coke completely in carrying out the calorific value test. The writer finds it advisable to proceed as follows:

Weigh out 0·200 gramme of finely-powdered pure sugar into the capsule or crucible; add 1·000 gramme of very finely powdered dry coke; mix the two carefully with a fine polished wire, and fire at a pressure of 30 atmospheres of oxygen, afterwards making the necessary deduction for the sugar added. The sugar ensures complete combustion of the mixture.

(*b*) The ash content is undoubtedly a serious handicap, as already observed.

(*c*) Moisture is taken up by coke more or less as a sponge absorbs water. The coke does not show a large content of (say) 10 or 12 p.ct. in an apparent way as coal does. There is, in fact, a great tendency to over-quench coke.

(*d*) Difficulty of Ignition.—This is a disadvantage which often has the result by itself of turning the household against coke. Dry coke is much more easily ignited than wet; and, when unfortunately wet coke is supplied to the house, the householder may find it advisable to have a small store of dried coke (about 1 in. in size) with which to start his fire. As already indicated, the ignitibility with the same class of coke is largely dependent on the volatile content. At any rate this is my general experience. Not that there is any real difficulty in starting a coke fire, especially if a gas poker be brought into requisition, and a suitable grate with ample air spaces and good depth is used.

(*e*) Bulkiness is a disadvantage of gas coke as far as storage and transport are concerned. Ordinary gas coals have a volume of 40 to 45 c.ft. per ton, gas coke nuts about 65 to 75, so that it may be said that coke requires about 50 p.ct. more storage capacity than the same weight of coal. The cost of transport of coke by railway wagon, lorry, or cart is thus increased.

(*f*) Sulphur in coke makes its presence felt much more distinctly than the same percentage does in coal. The result is that a temporary down-draught in a chimney-flue taking the products of combustion of a coke fire is immediately detected by the pungent smell of sulphur dioxide that ensues. When there is a similar down-draught with a coal fire, there is undoubtedly a similar amount of sulphur dioxide brought into the room; but its presence is not detected because it is masked by the smoke, which contains evil-smelling tar oils. As a matter of fact, the percentage of combustible sulphur in coke is as a rule pretty much the same as in the coal from which it is made. A coal containing, for example, 1·5 p.ct. (33⅓ lbs. per ton) of combustible sulphur will on carbonizing produce in sulphurous gases (chiefly sulphuretted hydrogen and carbon disulphide) and oils 0·5 p.ct. (about 11 lbs. per ton). There will remain in the coke the other 1 p.ct., or 22⅔ lbs., which will represent on two-thirds of a ton (the weight of coke) again 1·5 p.ct. The nature of the sulphur compounds in the coal is, of course, altered, but this is a question that we need hardly discuss in this paper.

(*g*) The necessity for a deep bed of coke in all coke fires is well known. This arises from the fact that a good draught of air is required to maintain the coke in a state of combustion. A deep bed of coke of (say) 5 or 6 in. in an open house fire creates its own chimney effect, increasing as it warms up by the use of the kindling agent, gas or wood, the velocity of the upward current of air. Once the coke is incandescent, the draught is sufficient until the coke burns down to a depth of 2 to 3 in., or until the interstices are choked by dust. Coal, on the other hand, requires but a very shallow bed; and a lump of 6 in. or more can generally be depended on to burn slowly until almost entirely consumed.

In my present house, I may mention, I encountered a well grate which I assumed at first would not burn coke satisfactorily. For a short time I was forced to burn coal, and found that with a west wind there was great smoke nuisance through down-draught. By blanking up the face of the fire, raising the grate, and inserting a removable loose front, 6½ in. deep, I found there was no difficulty at all in burning gas coke, and there was no smoke nuisance or down-draught when the west wind blew.

(*h*) Probably not so Efficient for Boilers.—Though the Nicol "Sandwich" system has done a great deal towards popularizing the use of coke for boilers, I am of opinion (and I speak from experience and result of tests) that no great field for the use of coke in this way will be opened up. As already mentioned, the price of the therm in the form of coke will be a deciding factor. It is almost impossible to improve upon the thermal efficiencies now obtainable from the best-designed boiler plant using either cheap coal or powdered fuel. The best boiler plant gives a steam-raising thermal efficiency of 82 p.ct. on coal containing as much as 25 p.ct. of ash. As regards locomotives, the use of coke would not be attractive, for many reasons.

V. Possible General Improvements in Coke Production.

1. *Handling.*—It goes without saying that the coke made should be handled from the time it leaves the retort in such a way as to entail a minimum of breakage, and especially of dust formation. The gravity-bucket conveyor used on continuous vertical retort installations appears to the writer to leave little to be desired. With reference to horizontal retorts, a preliminary dowsing with water, and the carrying of large volumes of coke to a quenching stack would appear to meet the requirements as well as any method.

2. *Quenching.*—Various methods of quenching red-hot coke, by coke breeze, by cold waste gases, &c., have been tried so as to avoid the use of water, but I believe with only partial success. The writer has no new process to suggest. Coke quenched quickly in large masses has a better grey appearance than coke which is allowed to remain red-hot for a long period, and thereby partly burn away. Any system of quenching should provide a coke containing not more than 4 p.ct. of moisture.

3. *Ash Content.*—This I regard as the master key to the whole coke problem. When one has an intimate knowledge of the quality of coals bought and sold, one also knows what percentage of ash he may expect to find in the coke made from these coals. It is not surprising, therefore, to find that the gas coke usually supplied (and I have tested consignments from a good many undertakings) usually contains 14 p.ct., and in some cases over 22 p.ct., of ash (on dry basis). When it is remembered that ordinary house coal (screened round coal) contains only 4 to 6 p.ct. of ash, the difference must be acknowledged to be very striking indeed, making it a matter for little surprise that gas coke is not always held in great esteem.

4. *Sulphur Content.*—This again is capable of great improvement. The remedy for high ash and sulphur content lies in a knowledge and choice of coals.

VI. Smokeless Fuel for the House.

Being of opinion that the general improvements indicated are all that is necessary to maintain and increase the general demand for gas coke for sundry purposes, I will now deal with what I regard as the main problem—the provision of an acceptable house fuel to take the place of coal.

1. *Essential Features of a Satisfactory House Fuel.*—At the risk of repetition I will briefly state the requirements which in my opinion will give satisfaction. These are:

(*a*) *Presence of Volatile Matter.*—This is necessary to provide easy ignition, and to give a fire with a moderate flame, which makes it more lively and cheerful in an open grate. Volatile matter should not be less than 3 p.ct.

(*b*) *Dry Condition.*—This is also essential for ease of lighting and ready burning, and gives the customer full value for his money.

(*c*) *Low Ash Content.*—This gives less trouble in stoking, more heat, greater satisfaction in every way to the consumer.

(*d*) *Suitable Size.*—This is most important, as already pointed out. You might as well throw half-bricks on the fire as the 3 in. lumps of coke that sometimes form a considerable percentage of a load of "broken coke" supplied from gas-works devoid of proper screening plant.

(*e*) *Density.*—I do not regard this as of great importance, having used coke nuts made by all types of carbonizing plant and from a variety of coals without much trouble except as regards the ash. The denser cokes, however, are the least satisfactory.

I am strongly of opinion that there is no real need for low-temperature coke, such as "Coalite," containing from 5 to 10 p.ct. of volatile matter, though this certainly ignites more readily, and can be fired in larger lumps, than gas coke.

The best coke I have ever used is oil-coke made as a residue from the fire stills of a petroleum oil refinery. This lights very readily, burns with a very cheerful glow even in shallow layers or in 3 in. lumps, and leaves very little ash (about 2 p.ct.). The ash consists mainly of sodium sulphate and carbonate, and, being partly volatile, imparts a pleasing yellowish tinge to the flame. The calorific value is 15,020, the volatile content about 10 p.ct. The price is rather excessive—90s. per ton delivered in sacks. This high price gives one some idea of the demand that might be created for a really good smokeless fuel.

2. *Choice of Coals.*—The vital problem being the reduction of the ash content of the coke, the only way to success is to choose coals low in ash. Removal of "bats" (impurities consisting of burnt clay, shale, &c.) from the coke as it is conveyed on a picking belt would only be a makeshift, and would probably reduce the ash only by 1 to 2 units p.ct. at most.

Gas coals are invariably bought "unscreened," containing about 40 p.ct. of "smalls" passing through ½-in. mesh. Without serious error, we may assume the ash content in coal supplied in bulk to the average gas undertaking to be roundly 10 p.ct. As a result of various tests, I find the small coal contains 15 to 18 p.ct., and the large coal 5 or 6 p.ct. of ash. One solution of the problem would, therefore, be the purchase of screened coal. The screened coal would be worth about 1s. a ton more reckoned on an ash basis only. It would be worth an additional 3d., probably, from the point of view of transport, carbonizing costs, and other charges. No doubt the collieries would require a much larger increase of price than 1s. 3d., however, and it is therefore perhaps not advisable to make so drastic a change in the system of buying.

There is no doubt that far too little attention is paid by most gas undertakings to the quality of gas coals as regards ash

content. They are too prone to attach all importance to gas yield as a criterion of quality. On the Continent, I understand, it is customary for coal suppliers to give guarantees of ash content and often of calorific value. Even exporters in the Newcastle-on-Tyne district who buy coking coals from the collieries to make up mixed cargoes for the Continent have to guarantee that the ash will not exceed a certain figure, suffering a penalty if it is proved to do so, and receiving a percentage from the buyers if it falls below the mark.

Under the customary lax methods of buying gas coals the suppliers are not constrained to exert themselves sufficiently to clean the coal properly. It is profitable, in the absence of guarantees, for both miners and colliery owners to increase the output of coal, and there is a natural tendency, therefore, to work for quantity rather than quality. It is a short-sighted policy.

The modern "American" coal cutting machine is the cause of a good deal of the ash trouble by cutting into the "dirt" beneath the seam, producing "fines" containing an inordinate proportion of ash.

All this points to the necessity for standardization of the quality of gas coals. What is really wanted is a combined effort on the part of gas undertakings to regulate, in the first place, the ash content of coal and coke. I would suggest a maximum of 8 p.ct. in coal and 12 p.ct. in coke, to begin with.

As a means of control, coals should be sampled and analyzed systematically, preferably at the loading points—that is, either at the chutes delivering into the ship's hold or at the chutes at the colliery where the coal is being delivered into railway wagons. It is recognized that the more reliable method of sampling is from the stream of coal rather than from the wagon or heap, where segregation of "fines" and large coal unavoidably takes place. Moreover, the sampling would have the advantage of being open to the inspection of the colliery management in the former case.

Washing and Cleaning.—As a rule, it would be very awkward to clean the coal on the gas-works. After all, it is the business of the colliery. Some of the more progressive collieries in the North have had washeries, chiefly for coke-oven purposes, for a good many years, and others are beginning to instal dry cleaning appliances to deal with the small gas coal which is practically impossible to clean on the picking belt. A few gas undertakings, recognizing the importance of supplying satisfactory coke, buy considerable quantities of "washed nuts" and "washed peas," in which the moisture is about 5 p.ct. and the ash a like figure. As a control of the quality of the washing, a flotation test is of great assistance, in addition to the ash test. This may be carried out by determining the percentage of "sinkings" in brine of specific gravity 1·35.

Mixing or Grading of Coals.—There do not seem to me to be great possibilities in the direction of mixing or grading the coals, delivered, as they are, in train or ship loads to the larger gas-works, nor to my mind does the quality of the coke call urgently for this. It would no doubt in some cases be an advantage to bring into use a weakly caking coal of good gas yield by mixing it with a coking coal, thereby making a moderately dense, useful coke. Again, for the sake of better output and easier working in continuous vertical retorts, it may be thought desirable to reduce the plasticity of certain Durham coals by the admixture of low-caking Northumberland or Derbyshire coals. The kind of grading and mixing that is not infrequently done at the colliery, where several seams of different qualities are usually worked, is carried out more to suit the convenience of the working of the pits than to suit the buyers' wishes, and may be objectionable from the gas manufacturer's point of view.

The method of intimately mixing and briquetting coke dust and fine coal, as described by E. V. Evans ("Gas Journal," March 12, 1924), with a view to producing smokeless house fuel seems to me worthy of special notice, as the process might well prove a very useful adjunct to the larger gas undertakings, seeing that it would enable them to utilize the surplus coke dust unavoidably made in breaking the ordinary large coke to smaller size—a practice which will, in my opinion, prove to be a necessity in the future.

[Owing to very special circumstances, the writer of this paper does not wish his remarks on "Choice of Process" to be published fully at the present time]

Having regard to the present pressing need of the industry, the more important progressive steps that the writer would recommend to be taken might be summarized as follows:

(1) Strict control of ash content of gas coals.
(2) Control of coke quenching so as to limit the moisture content to 4 p.ct.
(3) Increasing the volatile content of the coke to 3 p.ct. by restricting retort temperature.
(4) Installation of complete gasification plants of various kinds as an adjunct to retort plant.
(5) Reduction of the calorific value standard, wherever possible, to permit of the full use of the gasification of coal as an auxiliary (or total substitute) in the production of town gas.

SECTION I.—COKE PRODUCTION.—(*Continued*).

Fifth Award, won by "Fuel."

BY MR. NORMAN J. IVISON, B.Sc.(LOND.), OF NEWCASTLE-UPON-TYNE.

Introductory.

The importance of coal as one of our chief natural resources can hardly be gainsaid, but in view of the fact that our supplies are limited, it behoves us to consider how the remainder can be utilized to the greatest possible advantage.

The continued use of coal in the raw state for domestic and industrial purposes is to be deprecated not only because of the smoke nuisance which is created, but because of the waste involved. Endeavours should be made to convert coal into products in which the potential energy would be more readily available. The gas industry converts coal into such forms, but the coal dealt with is only a fraction of the total used annually. The chief product of the industry—gas—has compelled attention from industrial and domestic users, because of its cleanliness and other obvious good qualities; and, as the records of various gas companies show, sales have increased steadily. This involves an increasing production of coke, which has to be disposed of as advantageously as possible. It is extremely probable that in the future the sales of coke will be largely dependent upon an increased utilization on the part of the ordinary householder. It is important, therefore, that the industry should be alive to its opportunity, and gain a strong and expanding foothold in this field.

Preliminary Treatment of Coal.

Coal, as it arrives at the surface of the mine, is a complex mixture of large and small material, slate, pyrites, and so on. It is very necessary that this mixture should be cleaned and graded, if the greatest efficiency of gas and coke manufacture is to be attained. The practice of dispatching coal containing stone and pyrites to gas-works ought to be suspended, for the presence of lumps of stone in the resultant coke leads to complaints on the part of the consumers. It has been found that (say) 6 p.ct. of ash finely distributed in the coke is not so deleterious to sales as 3 p.ct. present in the form of large stones. It is possible that a cleaning and grading plant for coal will form part of the future equipment of gas-works.

The general effect of high ash content is to weaken the coke, but coals containing a moderate and finely distributed amount occasionally yield a stronger coke than a coal with a very small percentage. This is owing, presumably, to a slight binding action on the part of the less refractory portions of the mineral matter.

Constitution of Coal.

For a complete knowledge of gas and coke production, it is necessary to consider the constitution of the initial material. The complexity of coal is such, however, as to have defied complete analysis up to the present time.

For the present purpose there are several classifications relevant to the study of carbonization. These, for the most part, are purely empirical, and have no definite scientific meaning in the full sense of that term.

Coal is generally considered to have three main ingredients:

A. Cellulosic substances.
B. Nitrogenous substances.
C. Resinic substances.

It seems probable that the resinic portion is the most important from the point of coking properties.

It is possible to extract from coal certain distinct classes of compounds by means of various solvents. Pyridine has proved to be one of the most useful of the latter, and was first used by Bedson. From the first experiments an empirical method of testing bituminous coals has been developed by Illingworth, Wheeler, and others. Three main constituents have been isolated, as follows:

A. Alpha compounds—insoluble in pyridine.
B. Beta compounds—soluble in pyridine, but insoluble in chloroform.
C. Gamma compounds—soluble in pyridine and chloroform.

The coking properties of coal are supposed to reside in the third, or gamma, group. This group of compounds, when distilled, yields rich liquid hydrocarbons, but no phenols; while the first two give small percentages of phenols, constituting the greater part of the liquid products.

Stopes has recognized four different constituents in ordinary banded bituminous coal.

A. Clarain.
B. Vitrain.
C. Durain, or "dull coal."
D. Fusain, or "mother of coal."

The first two preponderate in a good bright coal, and both have comparatively good coking properties. Durain is only slightly coking, while fusain refuses to coke at all, giving a fine powder.

The presence of durain and fusain is to be avoided in the ordinary way, but recent investigations by Weyman (J.S.C.I., 1925, 47T) have shown that in certain circumstances fusain may have a beneficial effect. Figures are given showing that mixing fusain coal with bright coal in a fine state of division results in a harder coke than that produced from the bright coal alone. In addition, the ignition temperature is fairly low, and the rapidity of ignition good—important considerations when coke is used in domestic appliances. Such a mixture could not be used in actual gas manufacture; it would, however, be possible to briquette material of this type with every advantage. The fusain, being non-coking, would tend to restrict the formation of a plastic layer during carbonization; and therefore a higher rate of gas evolution could be looked for.

With the more general adoption of facilities for coal blending and briquetting in gas-works, it may be practicable to utilize the knowledge which has been gained of the various constituents of coal in such a manner as to improve the products.

Sizes of Coal Carbonized.

It is now recognized that the size of the coal used in gas production has an important bearing both on the quality of the coke and on the rate of gas evolution. This is more apparent in vertical retorts than in horizontal retorts, for in the latter the effect produced by any factors influencing the rate of carbonization is usually masked, owing to the technique of the process.

The relation of the size of the coal to the size of the retort has special significance, and certain working limits have to be recognized. If the coal consists of pieces larger than a critical size, the coke produced is incompletely carbonized, while if the size is too small, the same effect is observed. The cause of this is different in the two cases, for in the first the heat has to penetrate large solid lumps, which it cannot readily do owing to the low conductivity, and in the second a plastic layer is more easily set-up, and this offers considerable resistance to the flow of heat towards the centre of the charge.

Coal dust is a frequent source of trouble in continuous vertical retorts, and occasionally the utmost difficulty is experienced in persuading the charge to descend the retort. A change in the rate of carbonization amounting to 20 p.ct. is not uncommon, and can often be attributed mainly to this cause.

Horizontal retorts will carbonize fairly small coal without any serious difficulty, but it is wise to see that the material is not too wet; for such coal, on being projected into the retort by a charging machine, cakes partially as soon as it reaches the heat, and falls in the mouth-piece.

As has been said, the size of the coal has also some effect on the quality of the coke. Use of finely-divided coal usually results in the formation of a harder, more dense, and homogeneous coke; but the ignition temperature is often raised somewhat, owing to more even heat treatment. With larger coal, partially carbonized and active residues are left which cause the ignition temperature to be lowered. If we consider, however, the time necessary to produce a freely burning fire, the latter coke will be found to be distinctly inferior to that produced from small coal; the difference amounting in many cases to over 100 p.ct.

With ordinary gas-works facilities, it is therefore advantageous to fix upon some suitable sizes which will combine, as far as possible, the advantages of both large and small coal. It has been found that nuts of a size equivalent to cubes of 2 in. down to ½ in. are suitable for use in vertical and horizontal retorts.

Carbonization of Coal.

The two main methods used in gas production—namely, by vertical and horizontal retorts—are those to be studied in connection with coke production. The mode of operation in the two cases is so different that considerable differences in the resultant coke are to be expected.

The coke produced from horizontal retorts differs according to the weight of the charge. That made from light charges is rather small and porous, possessing in general a higher ignition point than that made from heavy charges. Continuous vertical retorts produce coke of an analogous nature. Heavy charges, on the other hand, give a large dense product, as do intermittent verticals.

The almost universal practice of steaming continuous vertical retorts undoubtedly has an effect upon the coke made by this process. This is particularly noticeable with those easily-carbonized coals which have a high volatile matter content and give poor porous cokes. These coals are probably steamed with greater advantages than those with a low rate of carbonization, as the porous nature of the material renders it peculiarly susceptible to the action of steam. Generally speaking, the carbonizer has to weigh the advantages of extra gaseous therms against a loss in the form of poor coke, for with steaming these coals yield a larger percentage of breeze than they would ordinarily give.

When the properties of the coke from continuous vertical retorts are compared with those of the coke from horizontal retorts, it is seen that the former appears to have had a more severe thermal treatment. In many cases the volatile matter is lower and the combustibility considerably higher, but it is doubtful whether these differences are due to the actual heat treatment. The lower volatile matter may possibly be accounted for by the distilling action of the steam. This agent may also be responsible for the difference in combustibility, for the active portions of the coke surface would be most attacked. It must be remembered that steaming is essentially an oxidizing action so far as the coke is concerned; and substances which are oxidized on the surface are generally inert.

Temperature of Carbonization.

The temperature at which coal is carbonized has important bearings on the structure and properties of the resulting coke. Cobb and Greenwood, in their examination of the effect of heat on coal, found that low-temperature working resulted in the formation of swollen, porous, and weak coke. Carbonization at gas-works temperatures—*i.e.*, about 900° C.—gave a coke which was harder but more porous; the hardening being accompanied, apparently, by a thinning of the cell walls. At temperatures of about 1100° C., corresponding to coke-oven practice, the coke became more dense and harder; the latter property, in this case, resulting from a thickening of the cell walls.

The ignition point and free-burning characteristics are affected progressively by the heat treatment; the three stages given above corresponding to increments in these properties. It is noteworthy that coke from ovens, analogous to that of the third stage, can be made to burn freely in a shorter time after the ignition point is reached than coke from continuous vertical retorts, although the former is subjected to a more severe heat treatment. This is significant in view of the suggestion made as to the action of steam, and mentioned in the preceding section.

The general practice in gas-works is to work at the lowest temperature consistent with the economical extraction of gaseous therms; but if a good fuel suitable for domestic use is to be made, it is important to bear in mind the fact that the ignition temperature of the coke rises very much faster than the volatile matter decreases.

This latter fact is closely linked up with the question of the time element in carbonization. It has been established that prolonged heating has a detrimental effect upon the quality of the coke produced, which is not compensated for by the increased yield of gaseous therms. According to Weyman (*loc. cit.*), coke, when subjected to prolonged heat treatment, undergoes a process of polymerization, which results in a product of low activity.

Possible Developments in Carbonizing Practice.

The level of present-day carbonizing efficiency must be rated very highly, so that much improvement in the existing plant cannot be looked for. It is probable that such subjects as the low-temperature carbonization of coal will engage the attention of gas engineers to a greater degree as time goes on. The plants erected for this process have hitherto suffered from serious objections, particularly with regard to the thermal efficiency of the settings, the production of dilute ammoniacal liquor, and so on; but it seems feasible for a gas-works to include equipment of this kind. Briquettes might be made, using producer gas or waste gas as the heating medium.

Another development may be in the preheating of coal. This has been shown to have an important effect upon the coke and gas. The coke is rendered more dense and harder, while the yield of gaseous therms is increased. Preheating, to be effective, must be carried-out at the correct temperature; for different types of coal commence to decompose at different points. Waste gas could be used for this purpose if the amount passing through the preheating vessel was carefully regulated so as to maintain a constant temperature. It would also be advisable to arrange for the transfer of the preheated coal to the retort without exposure to air. This would not present any great difficulty with vertical retort installations.

Blending of Coals.

A small gas-works can frequently rely upon a fixed supply of one coal, which enables the carbonizing plant to be adjusted to a fine pitch. On the other hand, large works generally draw their supplies from many different sources, and as a result are faced with the problem of having to alter the conditions of distillation from time to time, in order to obtain uniform results.

There are two main types of coal with which gas engineers may have to deal—namely, swelling and non-swelling coals. As a rule, those coals which show marked swelling properties are avoided. The swelling coals are characterized by the formation of a coke occupying a greater volume than that of the original coal. This leads to the charge sticking in the retort; and the pressure on the walls may become so great as to cause serious damage. Vertical retorts are especially susceptible to changes in coal; and the introduction of a swelling coal may result in stoppages and a considerable decrease in the daily output. Non-swelling coals give coke of equal or less volume than that of the coal, but generally speaking the coke is poor in quality, and friable.

The trouble arising from the use of swelling coals may be obviated by preliminary heat treatment, by blending with the non-swelling variety or with coke breeze. It is extremely probable that, if the domestic fuel market is to be captured for coke, recourse will have to be made to some form of coal blending, in order to obtain a product which will be uniform and homogeneous. Coal is such a heterogeneous substance that considerable difficulty is to be anticipated in securing a correct and intimate mixture. If coke breeze is to be blended with coal, it is imperative that both should be in a fine state of division if the best results are to be obtained; and this also applies to pure coal blending. This entails the use of pulverizing and briquetting plants; but the capital cost of these is not excessive, and in the future is likely to decrease. The proportion of breeze to be used on non-swelling coal depends upon the type of coal to be blended, the conditions in the retort house, the thermal yield required, and other factors.

The correct mixture for each coal can be determined by experiment on a small scale. It is conceivable that in certain circumstances coke breeze blending might become uneconomical. In those works unprovided with proper facilities for coal blending, much can be done in this way if care is taken, though a really high efficiency is hardly to be expected. Improved results have been obtained with vertical retorts simply by causing two different coals to mix together before reaching the breaker.

The properties of the coke resulting from a blended coal depend upon the characteristics of the original constituents, but it does not necessarily follow that the distinguishing features of the coke will be the mean of those appertaining to the cokes produced from the separate coals.

Quenching of Coke.

It is important that coke to be used by domestic households should be reasonably dry, for the presence of moisture entails a loss of heat in evaporation, and in addition wet coke is often ejected from a hot fire with almost explosive violence.

Continuous vertical retorts fitted with steaming apparatus usually discharge their coke at quite a low temperature and with a moisture content of less than 0·5 p.ct. Horizontal retort installations, however, are usually unprovided with any dry cooling plant, and the moisture may be as high as 5 p.ct. or more. Quenching by means of immersion in water or spraying is most wasteful, especially from the thermal point of view, for all the heat in the coke is dissipated, whereas in a certain continuous vertical retort plant 40 p.ct. of the heat of the coke is recovered and returned to the setting. Other disadvantages of water quenching are the large volume of water required, the necessity for providing pumps, mains and hoses, cooling and filtering beds, and so on. Those systems of water quenching in which the coke is ejected on to a conveyor sprayed with water show poor design in some instances, for the fuel from one end of the retort bench may be absolutely saturated, while at the other it may be almost glowing. It is frequently noticed that considerable wear and tear is involved by wet quenching inside the retort house, particularly with regard to mouthpieces and roof ironwork. This is due to the presence of sulphuric acid in the water vapour. The quality of the coke is also adversely affected, for disintegration occurs, with production of breeze.

Principles of Dry Cooling.

In dry cooling processes the hot coke is enclosed in a chamber, through which is circulated nitrogen or some other inert gas. Air may be used, as the oxygen is quickly removed by the hot coke, leaving nitrogen, which can then be passed through a boiler. Steam may be raised to any desired pressure in the boiler, or large supplies of hot water can be prepared.

In the Sulzer plant the gases are circulated, by an electric fan, through a firetube boiler having two drums, and the coke is cooled from about 2000° to about 400° Fahr. The steam pressure is regulated by the speed of the fan, and the fixing of an automatic control would be a simple matter.

Particulars of efficiency tests obtained in Continental works are given below, and are commendable. ("Engineer," 1925.)

Capacity of plant per hour	6 tons of coke
Boiler pressure	145 lbs. per sq. in.
Temperature of feed water	57° Fahr.
Steam raised per ton of coke cooled, at 124 lbs. per sq. in.	467 kilos.
Average temperature of coke at charge	1092° C.
Average temperature of coke at discharge	212° C.
Efficiency	80·2 p.ct.

The coke is bright, dry, large, and compact, and has a higher calorific value than the water-cooled substance. The amount of breeze is also greatly reduced.

Conclusion.

The essentials of a good domestic and industrial coke may be summarized as follows:

(*a*) Low moisture and ash content.
(*b*) Good combustibility.
(*c*) Uniform and homogeneous structure.
(*d*) Suitable size, and cleanliness.

The properties, of which (*a*) and (*d*) are probably the most important, can easily be obtained by the exercise of care in carbonizing and subsequent handling.

SECTION II.

COKE PREPARATION.

First Award, won by "Labetur in Omne Volubilis Aevum."

BY MR. F. M. BIRKS, O.B.E., M.I.Mech.E., OF BECKTON.

In a general survey of the question of the preparation of coke, it must be remembered that at this stage in the history of gas-making an overwhelming proportion of the output of gas coke must necessarily be produced by works which in many cases have been in existence for a great number of years. It therefore goes without saying that each individual scheme must receive special consideration to enable it to meet the particular circumstances which may already exist.

The relationship between costs and a well-thought-out flow, when handling masses of any class of material, are so well recognized by modern engineers that new works under consideration to-day invariably receive adequate attention in this respect.

Generally, the points which can be taken as indicating a coke of high quality are:

(1) Freedom from moisture.
(2) Freedom from ash.
(3) Perfect classification as to size.

For the purpose of this paper, gas-coke producing plants can be divided up under two headings—viz., (*a*) those provided with retorts which produce coke at such a temperature that no subsequent quenching is necessary, which coke in consequence is free from moisture; and (*b*) those provided with retorts or ovens from which the coke is ejected at such a temperature that combustion would continue if provision was not made to extract the surplus heat.

The usual method of cooling coke is to bring it in contact with water, sufficient water only being applied to reduce the temperature to a point where combustion ceases; any further addition of water resulting in moisture in the coke. I need hardly say that the perfect proportion of water to meet this requirement by mechanical means is a difficult problem. Further, this method results in large volumes of steam being generated, by which a great quantity of heat is wasted annually.

Of recent years a method of dry quenching has been evolved which reduces the temperature of the coke by passing inert gases in a closed system alternately through it and through a suitable boiler. By this means the coke is quenched free from moisture, while a considerable and valuable percentage of the heat can be converted into useful work. The greatest obstacle to the general adoption of this method is the question of the large capital outlay involved—an obstacle which time will probably tend to remove.

Freedom from ash has only a bearing on this paper inasmuch as it effects the recovery of coke from pan ash; and its solution appears to be in the judicious selection of coals more or less free from inherent ash, together with the removal of shale at the pit. The reduction of ash by this means is likely in the future to receive greater attention, as the economies to be obtained appear substantial; the principal ones being as follows:

Saving in freight by rail and sea, due to the greater number of B.Th.U. carried per cubic foot of cargo space.

Relatively increased capacity of the carbonizing plant, resulting in decreased capital, operating, and maintenance charges, due to the less throughput per cubic foot of gas output.

More perfect combustion and control of heats in producers, due to the diminution of pan ash.

Minimum ash contents in coke, resulting in a better market quality.

Perfect classification is obtained by the careful operation and maintenance of scientifically-designed screening plants, with the subsequent handling of the coke in such a manner that the sizing is not further reduced by breakage.

Coke made in gas-works is disposed of internally in the works itself, for heating producers, the manufacture of water gas, the generation of steam, and various incidental purposes, and the balance is sold on the open market. The market varies in different localities as to the size of the coke required; and in certain districts it may even be necessary to crush, so as to meet the demands for smaller sizes. Generally, for export, large size is preferable—from 2½ in. cube upwards. It has been the practice for many years to retain breeze at the works for use on the boilers; but with the economies that can be effected by utilizing the heat in waste gases for this purpose, it may be necessary in some cases to find a market for it. There should be no difficulty in obtaining a ready sale for fine breeze, as in most districts there are many works with water-tube boilers fitted with mechanical stokers, for which it is a valuable fuel.

To retain markets for this product, two points must receive attention—(1) that sufficient stock is retained, to ensure a regular supply; and (2) that the sizing is accurate, to obviate the customer re-screening. The fuel should be passed through a mesh not exceeding ½ in., if breeze only is to be used on the grates. If the coke is used in combination with coal slack, a greater margin in sizing can be allowed.

Sizes which can be taken as fairly general practice are:

Up to ½ in.
½ in. to ¾ ,,
¾ ,, to 1½ ,,
1½ ,, to 2½ ,,
2½ ,, and over.

These can be varied to suit any other requirements, by altering the mesh in the screens.

Stock requirements will partially vary with different localities; but, if sufficient ground is available, the stock heaps can be divided in two classes:

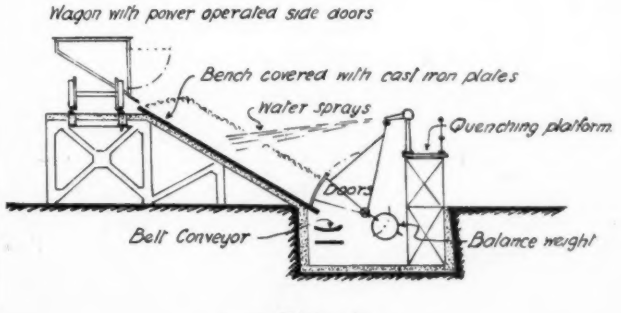
(1) A comparatively small stock of graded material used to balance the output so as to ensure a regular supply to customers, and to tide over delays caused by traffic or weather. This stock may be turned over many times per annum, and in many cases will warrant considerable expenditure on handling plant.

(2) Intermittent large stocks of ungraded or graded material due to market conditions. This stock is seldom turned over more than once a year, and will generally only warrant the employment of plant which can be turned to useful purposes when not required for handling stock heaps.

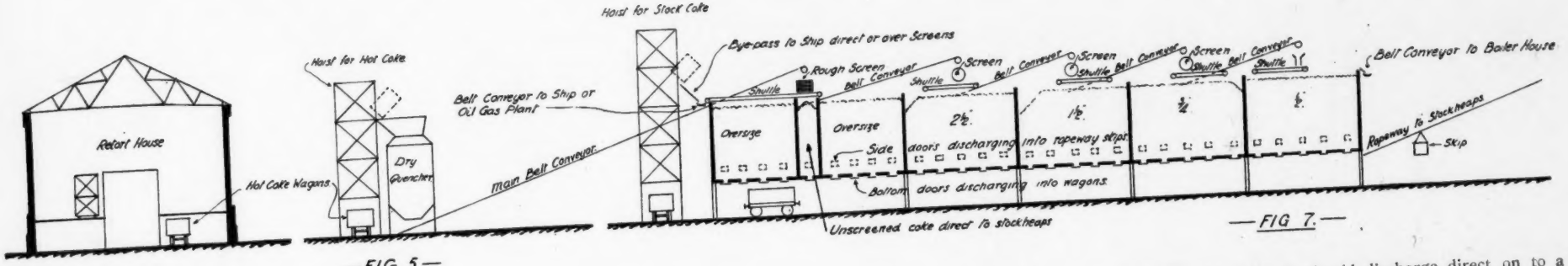
The greatest difficulty experienced in handling coke is due to its great abrasive qualities. In addition, when it is hot and wet quenched, considerable deterioration of plant is experienced by corrosion. Coke should, therefore, wherever possible, be carried, and not dragged, as this lessens breakage and the production of breeze. The greatest use should be made of cast iron and indiarubber, as they both resist abrasion and corrosion better than mild steel.

Maintenance of coke handling plants will for the same reason always be considerably heavier than similar plants handling coal. It therefore follows that maintenance should be an important factor in selecting plant. That this is often not so is because operating costs are easily obtained. They can be expressed at intervals of weeks or months in terms of throughput, and are a barometer which is generally considered indicative of efficiency. On the other hand, especially in small works, maintenance costs are frequently indeterminate, and plant may be kept running in a derelict condition until a general overhaul of the carbonizing plant allows an opportunity for wholesale replacements to the conveying plant, while at the same time the costs are merged into the work as a whole, and do not demonstrate the heavy maintenance charges of individual portions of the plant. Even in works where accurate detail costs are kept, some years must elapse before true average maintenance figures can be obtained.

It is not generally recognized that coke-handling plants are often included in a small category of machinery where the maintenance costs may be higher than either the operating or



—FIG 1.—



—FIG 2.— —FIG 5.— —FIG 7.—

capital charges; and a careful review of the situation as a whole may warrant an increase in capital and operating charges to enable a reduction to be made in the total costs.

With horizontal retorts or ovens, the first movement of the coke is to the quenching plant. It should then go to rough screens to remove any coke under (say) 2½ in.; the over size going on to stock heaps or to the loading place for sale. After rough screening, the through sizes should be transferred to classifying screens, to be graded out; each subsequent size being loaded for sale, internal use, or to stock heaps.

It should be noted that it is advisable to arrange that a proportion of the coke can be sent to the stock unscreened, direct from the quenching plant, and only enough passed over the rough screens to ensure a sufficient supply of smalls. As a general rule, it will be found advisable to limit stocks of smalls to quantities sufficient for balancing the output, though, of course, at times when demands for one particular size have to be met, comparatively large stocks of other sizes may be unavoidable.

It is desirable that the main stock heap should be returned through the screening plant for sale, and not sold direct from heap, as some breakage and the making of smalls is inevitable in stocking and picking up, though in certain circumstances, when a constant supply of smaller sizes is required, it may be necessary to stock the larger sizes after screening, in which case subsequent re-screening may be found too costly.

From the retorts to the quenching plant is by far the most difficult stage to handle the coke, owing to its heat. The methods which are in common use to-day are:

(1) Stage-level conveyors provided with quenching sprays or baths.
(2) Transporter skips delivering on to quenching benches.
(3) Wagons or skips in which the coke is run to either wet or dry quenching systems.

(1) The most usual type of stage-level conveyor is the drag-link conveyor, as originally introduced by De Brouwer. This conveyor has now been in use in gas-works for many years; and in spite of being contrary to all principles previously laid down, it has until recently been almost supreme, its high maintenance costs being mitigated to a great extent by its low operating costs. Probably, its continued use for so long has been due to lack of serious competitors, and the difficulty of applying other types to existing retort houses. One of the first attempts to improve it was to carry the coke on a tray conveyor. This was not successful, as the trays, by reason of their construction, could not be made water-tight, and fine breeze was washed-down on to the bearing, axles, and rails, resulting in excessive wear.

(2) Transporters delivering direct to quenching benches are an adaptation of modern coke-oven practice to retort houses. They are an advance on the drag-link conveyor, but are not as satisfactory from a maintenance point of view as with coke ovens, owing to the size of the units being so much smaller, and the movements of the machines correspondingly greater, for any given tonnage. It is difficult with this type to arrange for preliminary quenching. The whole of the quenching has to be carried out on the bench, which results in rather more wear and tear to the bench and fittings than when it is used for finishing-off the quenching only.

(3) Wagons or skips to carry the coke to the quenching bay were the first mechanical appliances used for the conveyance of hot coke. This system is still in use in a number of works, especially small ones. It is now coming rapidly into favour with coke ovens, where the size of the units and general layout of the plant lend themselves readily to this system. Its superiority in maintenance costs over any other type is considerable, while the operating costs are low.

The wagons should be of the largest size which the design of retorts will allow, and haulage should be electrical, preferably by electric locomotives, so as to keep the haulage mechanism as far away as possible from the effects of the heat and dust from the hot coke.

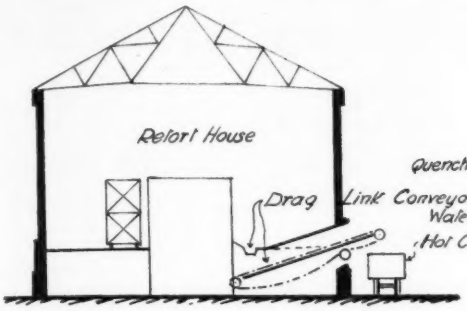
Further, this system lends itself admirably to dry quenching, though it is equally suitable for wet quenching in a tower, when the fumes and steam can be directed up to a suitable elevation before being allowed to escape. One of the difficulties experienced with bench quenching has been to ensure that the whole body of coke is quenched evenly, without leaving parts of the coke sodden with surplus water. By quenching as a preliminary operation in a tower, and afterwards discharging the partially-quenched coke on to a bench, the operation can be completed by hand-controlled jets, as the coke, in rolling down the bench, will expose any surfaces which may previously have missed coming in contact with the water.

The quenching bench should discharge direct on to a belt conveyor, as this allows the simplest type of door to be used, the working parts of which are protected as far as possible from heat, moisture, and coke dust, while the cost of picking-up spillage is reduced to a minimum. An arrangement of this type of bench is shown in fig. 1.

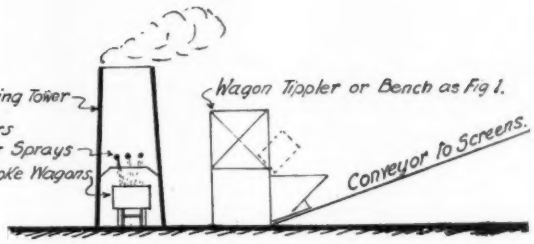
Telphers often appear an attractive means of conveying the skips, especially in small works, due to their ability to negotiate sharp radius curves, and to operate without interference with ordinary traffic at ground level. On the other hand, the maintenance of hoisting ropes is heavy when used for quenching, owing to their exposure to steam and fumes. Their operating costs are heavy if of the man-carrying type, any spillage on the stage has to be shovelled into the skips, while the overhead equipment is exposed to the corrosive atmosphere of the works, and, owing to its inaccessibility, is costly to maintain.

To apply coke-oven practice to existing retort houses is extremely difficult or even impossible in many works without complete reconstruction of carbonizing plant, owing to the design of producers and lay-out of buildings; but a compromise by combining these systems may often be possible. Fig. 2 shows under-stage wagons running at ground level on heavy permanent track of a gauge which lends itself to the minimum radius curves allowable. It will have low maintenance costs apart from the wagons, which are easily and comparatively cheaply repaired, and spillage on the stage can be easily swept into them. The haulage should be by small electric locomotives. Where it is not possible to arrange for wagons under the stage, drag-chain conveyors discharging into wagons or quenching baths, as shown in figs. 3 and 4, offer a part solution where capital cost is a serious consideration.

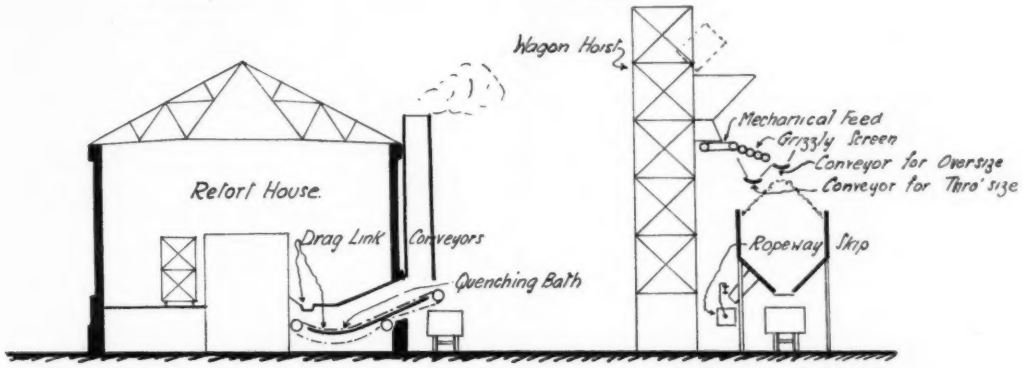
Accurate operating costs of these systems are easy to obtain, but maintenance costs are often difficult. In most classes of plant there is a general deterioration combined with obsolescence which can be defined within certain limits and can be expressed in terms of years, with a suitable depreciation fund. In these cases, there is a fairly even expenditure for small repairs annually. With conveyors working with hot coke, obsolescence is seldom reached before the plant has been worn-out completely, so that eventually it may be found that several reconstructions have been necessary, and that the original capital outlay has been expended many times over. An accurate



— FIG 3. —



— FIG 6. —



— FIG 4. —

— SECTION OF HOPPER —
With Hoist alternative to inclined conveyor

figure for maintenance can therefore only be obtained by taking an average over several years. After making due allowance for fluctuations of wages and materials, it will be found that conveyors of the drag type cost on to-day's prices approximately 2d. to 3d. per ton of coke to operate, and 6d. to 7d. per ton for maintenance—delivery to the outside of the retort house only, and screening and hoppering not included.

The cost of maintenance of a coke-oven type of plant should not exceed 1d. to 1½d. per ton handled. The nearer to this design existing plants can be adapted, the greater will be the corresponding saving in maintenance.

The quenching plant should be arranged, if possible, so that two or more retort houses can deliver coke to it—more especially if the draws can be arranged alternately—so as to lessen the labour costs. A dry quenching system will necessitate a hoist to lift the wagon containing the hot coke to the hopper level (fig. 5). This hoist can be arranged so as to discharge the coke automatically into the hopper, and one man should be sufficient for its operation, if the trucks are fitted with automatic couplings.

The wet quenching (fig. 6) will be easily operated, as the tower should be of sufficent capacity to accommodate more than one wagon, unless the wagons are of large capacity. In this case it will be necessary for the operator to tip the wagons for delivery to the rough screens. Any form of wet quenching will result in a certain amount of fine breeze being carried over by the water; and it is advisable to arrange suitable settling pits. The water can be used again after clarifying, if desired, while the fine breeze which can be salved from the pits, after being allowed to drain for some weeks, is a valuable fuel for boilers fitted with mechanical stokers.

A satisfactory screen must comply with two essential conditions. First, it must lift each individual piece of coke apart from its neighbours. Secondly, it must present each particle to a predetermined gauge in two dimensions, through which the under-sized pieces can pass without obstruction.

No form of bar screen can give perfect classification, as the sizing is in one dimension only. No form of screen can give perfect classification where coke is dragged or slides across the screen plate, as under-sized pieces will tend to ride over on the backs of the larger.

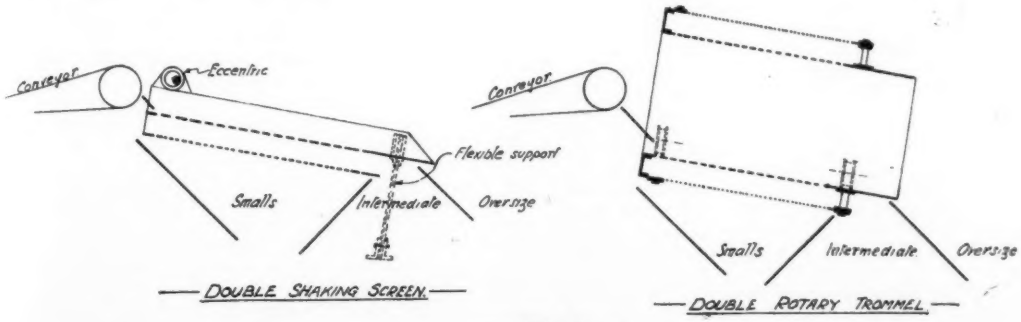
Generally it is desirable to rough screen as a preliminary operation, taking out all coke below 2½ in., after which the under sizes should be re-screened; the larger sizes being taken out first, until only the fine breeze is left.

An arrangement of screening plant suitable for large outputs is shown in fig. 7. It will be noted that belt conveyors are used for all movements of the coke; those over the hoppers being of the shuttle type. For small outputs this arrangement can be modified and cheapened, if desired, by making the hoppers smaller, dispensing with the shuttle conveyors, and making the screens of the multiple type, so that each screen classifies more than two sizes (fig. 8).

Rotary grizzlies, revolving trommels, and shaking screens are the best types at present in use. The rotary grizzly is an excellent screen for preliminary screening, being gentle in action, and having a high output. Its classification is not sufficiently good for fine screening. For fine screening, trommels and shaking screens give a classification which is superior to any other type.

No attempt should be made to combine conveying with screening, as the long rotary screen, mounted on a hopper, has done much to bring this type into ill-favour—all the large coke has to pass through the complete length of the screen, tending to increase the percentage of smalls in its passage. For the same reason the wear is heavy, while the great length and weight makes it difficult and costly to repair.

A trommel screen should be designed with a substantial framework. All parts which are exposed to the passage of the coke should be provided with renewable wearing plates, while the screening elements should be in easily renewable sections. The screens should be as short as possible consistent with good



— DOUBLE SHAKING SCREEN. —

— DOUBLE ROTARY TROMMEL. —

— FIG. 8. —

classification. The same remarks apply to shaking screens, but these by reason of their liability to vibrate cannot be made as substantial as rotaries.

Generally, there is often a tendency to crowd screens. This is fatal to perfect classification. Screening plants should be designed to have ample capacity for their work, and care should be taken to instal them well up to the highest peak likely to be obtained, as the feed is frequently intermittent, and they are often called upon to pass momentarily a quantity far in excess of the hourly output.

The maintenance of all screening plants is heavy. Thus too much attention cannot be paid to ensuring ease of renewal of wearing parts. It must not be overlooked that screening plants constantly driven to their maximum capacity do not give a higher return on their capital outlay, as is usual with most types of plant, but, owing to the increased wear and tear and the delays for repairs, frequently tend to lessen their earning capacity.

The screening plant described herein will not materially add to the labour costs over and above those in most works where the coke is only partially screened—in fact, in many works it should result in a decrease.

The capital charges will, of course, greatly depend on the size of the plant—the greater the capacity, the less the cost per ton handled. An average figure for a medium-size works may be taken at about 2d. per ton handled, including depreciation. The figure for wear and tear, as mentioned before, is difficult to estimate accurately. It is also a difficult figure to obtain for comparative purposes, as it increases with the age of the plant, and after a certain age often in a rapidly-ascending scale. The use of belt conveyors enables a near approximation to be made, for the life of belts should be at least 700,000 tons of coke carried, and as each belt is carrying a less quantity than the preceding one, the total costs should not exceed a maximum of 0·2d. per ton handled.

A point that should be noted is that shuttle belts have a great advantage over any other form of hopper conveyor, inasmuch as the framework and travelling gear are not subjected to any great wear, while the conveyor proper is approximately half the length of any other type, and therefore the wearing parts are correspondingly cheaper to renew. The screens are by far the most costly part of the plant to maintain, but by the use of renewable screening elements and renewable wearing parts, the maintenance should not exceed 1d. per ton handled. The total maintenance of the plant, inclusive, should not exceed 1·5d.

For moving coke over short distances, no type of conveyor can compare with the rubber belt, for its gentleness in action—if due attention is given to ensuring a short drop at the discharge end—results in a minimum breakage of the coke, while both operating and maintenance costs are low. When discharging into hopper it should be of the shuttle type in preference to the throw-off carriage, though the latter, in certain circumstances, may be found suitable. The greatest wear is on the return idler pulleys, which can be protected from the abrasive action of the breeze clinging to the belt, by covering them with rubber.

For longer distances the selection of tip wagons, telphers, or ropeways will depend on a careful analysis of the conditions. Telphers and ropeways have the advantage that they are able, by reason of their height, to deposit the coke on to stock heaps with a minimum of crushing. The ropeway is cheaper in operating costs, as the skips can be made to discharge automatically, and no driver is required to be carried. As either of the latter systems can carry one size only at a time, hoppers must be provided at the screens, so that each size can be cleared to stock at intervals, depending on the quantity of each size produced. These hoppers can be made of such a capacity as to form the balancing stocks, and should be arranged to discharge direct into railway wagons. They should preferably be of ferro-concrete, and should be protected from abrasion by cast-iron plates or hard bricks. If it is desired to load to ship, this can be arranged direct from the screens by means of belt conveyors or ropeways, depending on the distance to the point of shipment. If conveyors are used, it will be necessary to discharge coke in the hoppers for shipment into wagons, and a hoist can be used to lift the wagons to the conveyor level. The same hoist can be used for shipping coke from the stock heaps. For picking up from the stock heaps, portable cranes with grabs are the cheapest type of plant that can be used, and are probably the most profitable in a small works.

If the tonnage handled will warrant the expense, mechanical navvies mounted on caterpillar tracks are the most economical machines from the point of view of operating costs, while they have the further advantage that they cause less breakage of the coke than grabs, and do not require permanent or temporary tracks to be laid for them to run on.

The deterioration of coke through weathering in stock heaps is more apparent than real. Dust in the atmosphere deposits and washes into the surface, tending to give the coke a dirty appearance, which, though undesirable, does not materially detract from its value as a fuel. High stock heaps offer a minimum of exposed surface, besides being economical in space and plant. It is doubtful if there is any breakage of small coke in the heaps apart from that inevitable in handling; but there may be a certain amount of breakage of the large coke at the bottom of the heap by the superimposed weight of that above it, as there is a weakness in large coke which tends to cleavage along the lines of heat penetration into the charge. A height of about 40 ft. appears to be a good compromise.

If perfectly dry coke is stacked, it will absorb moisture from the atmosphere, and will eventually reach a moisture content of about 3 to 4 p.ct., depending to some extent on the time of the year. The moisture from wet coke will drain away until it reaches a similar point. The smaller the coke, the longer time required for it to drain and dry out.

Bucket elevators should never be used for coke unless the tonnage carried is small, as they are costly to maintain and are liable to breakdown. Inclined belt conveyors are the best means of lifting to a higher level, where space available will allow of their use. Wagon hoists are excellent for this service, more especially if large-capacity wagons can be used. For smaller capacities, skip hoists can be usefully employed, though breakage will be greater than with conveyors or wagon hoists. In vertical retort houses, the gravity-bucket conveyor lends itself to combined elevating and conveying more readily than any other type; and it is only natural that, when installed for filling the overhead coal bunkers, it should often be utilized for conveying the coke away from the retorts. This type of conveyor can never be entirely satisfactory for coke, as its many wearing parts are all subjected to the abrasive action of the coke dust. An advance on this type of plant is a combination of automatic skip hoists in conjunction with belt conveyors over the bunkers. Inclined belt conveyors offer an advantage over either of these types, more especially for plants of large capacity.

Crushing is at times a necessary evil—an evil in that the wear on any crushing plant is extremely heavy. Curiously enough, some works require to crush, and find it difficult, while others requiring large coke find it equally difficult to prevent breakage and the making of smalls. The latter usually pay great attention to the question of dropping coke. It is good practice always to leave a cone of coke in hoppers, &c. Then the discharge on to the heap can be arranged so that the coke rolls down the incline, and has a minimum vertical drop.

The "Bradford" coal breaker works on the principle of breaking coal by dropping it; the coal being continually elevated on to the inside of a large drum, and dropped from the top on to the coal at the bottom. It is doubtful if this particular design of breaker would be serviceable for coke, but the principle might be extended, and coke elevated to a considerable height by suitable means and then dropped on to a small heap of coke, which could be removed automatically as it made up. It would have the advantage that the coke would be broken by coke, and the wear and tear would be confined to the elevator, which, if of the rubber-belt type, would be low. Further, the time lost in repairs would be negligible. I anticipate that this method would tend to shatter the coke into small pieces and with a minimum of breeze.

Plants for the recovery of coke from pan ash are, at their best, an expedient to minimize the costs of unsatisfactory conditions; but until such time as the pan ash can be freed from combustible matter in the producers, they will be a necessary adjunct to carbonizing plants. I do not propose to give any detailed description of the various plants on the market, as they are all well known to everyone interested in the subject. On broad lines, there are two classes—wet and dry. The wet plants rely on various principles of flotation either in water or a mixture of water and suitable solid matter. The dry type works on the magnetic principle, and is only applicable when the ash is magnetic. Dry plants are of comparatively recent origin, and have the great advantage of producing a product with a minimum moisture content. Further, their efficiency is high, while their maintenance is low. Their future appears assured until such time as improvements in producers render them unnecessary.

SECTION II.—COKE PREPARATION.—(*Continued.*)

Second Award, won by "Carbon."

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COKE HANDLING.

The complete system* of handling coke described in this article is one that has been developed in America during the past twenty years, and is based on certain fundamental principles. The original development was made in connection with the bye-product coke oven industry, was later modified to suit gas-works requirements, and has been again modified to suit the different conditions obtaining in Great Britain.

The fundamentals on which this system is based are the following:

(1) Cheapness of handling by designing special apparatus to suit peculiar conditions, endeavouring to eliminate labour wherever possible, and use of machinery which can be operated by unskilled labour.
(2) Avoiding breakage of coke, principally by eliminating velocity.
(3) Concentration of attention on the oversize, rather than on the throughs.
(4) Use of central stations.

The specially designed, or adapted, machines of this system are the following (each is later described fully):

The belt conveyor.

Fig. 1.—General View of Coke Bench with Belt Conveyor carrying Coke to Screening Station.

The shuttle belt conveyor.
The loading boom belt conveyor.
The belt and bucket elevator.
The roll feeder.
The displacement feeder.
The telescopic anti-breakage chute, and special chutes.
The rotary grizzly.
The balanced (or grasshopper) screen.
The adjustable breaker.

As coke quenching is not to be considered in this article, the quenching methods used in this system are not described. Furthermore, this system does not cover the washing, settling, and hydraulic classifying of coke in its finest sizes.

CONVEYING.

Belt Conveyor.

Belt conveyors had been used for the transportation of coke, in a general way, as also for coal, stone, cement clinker, ores, and other heavy materials, before the great development of the coke oven; but, when Dr. Koppers, about twenty years ago, put into practice his idea of taking the burning coke away from the ovens in a car, quenching with a deluge of water in that car, and sliding the quenched coke for cooling on to a bench removed entirely from the ovens, and the United States Steel Corporation installed such a plant, the Coke Committee of the Corporation considered the arguments in favour of the belt conveyor to take the coke from the bench. After very close investigation of this and other methods, they decided in favour of the belt system.

The first installation of this kind was near Chicago (see fig. 1), and the belt conveyor designed by Robins for that plant is still in service. The success of this initial installation was such that in a very short period plants on this principle became the standard American practice. Those installations having the bench in front of the ovens have been similarly fitted; and all plant handling of coke, whether in bye-product or gas works, once the coke has been quenched, is now done with belt conveyors.

The separate coke bench, serving a number of coke-oven batteries, is now the established practice in America, as are also the central coal crushing station and the central coke screening station. It is becoming customary there in gas-works also to use the quenching car and separate coke bench for retort plants discharging hot coke, in order to remove the steam, caused by quenching, from the retort house; and, for self-cooling retort installations, the coke is also handled by belt conveyor (fig. 3).

The advantage of the belt conveyor in handling coke is that it gives a lower cost per ton of coke handled. This is due to less abrasion of the metal working parts, and less breakage of coke. The coke is only in contact with rubber (a material very resistant to wear and sulphuric acid) and does not touch the metal parts of the machine. Instead of being dragged or scraped along, the coke is carried by the rubber belt, and remains quiescent while on the belt. When belts are worn out and need replacing, the change of belts is quickly and easily made; and as the machinery gets little wear, it serves for many years. This effect on the conveyor was gained when trying for something else. The original idea was to seek a means of preventing breakage of the large pieces of coke, which, as "foundry" and "furnace" coke, fetch the highest prices in America. It was found that when this was achieved in conveying, screening, &c., that a type of plant least destructive to coke was least destroyed by coke.

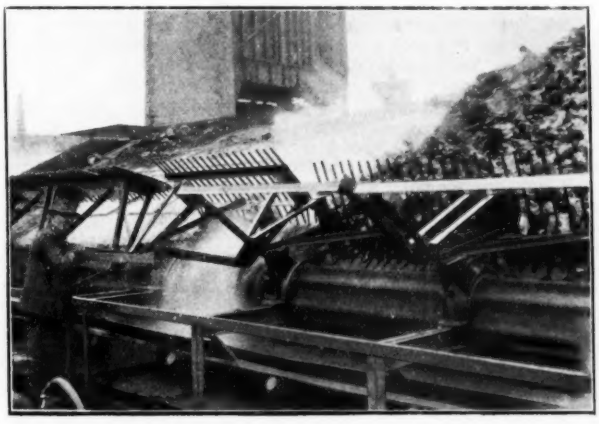


Fig. 2.—Coke Bench with Finger Gates and Roll Feeders Discharging Coke to Belt Conveyor.

In many of the early installations the benches were not made long enough, or other batteries of ovens were installed without increasing the size and capacity of the bench. The cooling time on the bench was thus decreased to such an extent that it was necessary to handle fairly hot coke on the belt conveyor. In some cases the belt had to carry the coke so soon after quenching, or perhaps after an insufficient quenching, that much of the coke was still very hot. The belt, of course, received many burns, but a red-hot burning piece of coke was seldom on the belt long enough to burn a hole through it. Generally, however, the rubber cover melted at that spot; and experiments were made to find a rubber compound which would harden again after this softening. After exhaustive and expensive experiments, this was accomplished. On this re-hardening, it was found that a considerable amount of coke dust had stuck to the softened rubber, and was now a part of the cover, making it almost as durable as before. Each burn injured the belt somewhat; but taking into consideration the

*The "Robins System," manufactured in England by Fraser & Chalmers Engineering Works (Proprietors, the General Electric Company, Ltd.), at Erith, Kent, associated with the Robins Conveying Belt Company.

width, length and speed of the belt, the law of averages was much against another burn in the same spot for a long time. The coke dust sticking to the cover of the hot coke belt made the belt cover very abrasive; and a different design of return idlers (the rollers supporting the lower strand of the belt which is upside down) was developed to discount this wear. On other conveyors farther along in the system, which handle cool coke, the dust is often removed from the belt by a broom-like revolving brush. It has been found in twenty years of practice that even when handling hot quenched coke, with a belt life sometimes, in extreme cases, of only twelve months, this is a very economical form of conveying, due to the fact that only the belt need be replaced. When cool coke is handled, the

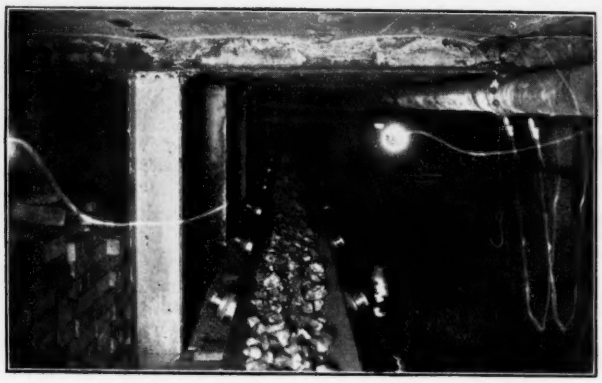


Fig. 3.—30. in. Belt Conveyor, 218 ft. long, carrying Coke to Water Gas Plant in a London Gas-Works.

conditions are much easier, and only the abrasive nature of the coke need be guarded against.

It is interesting to note the adaptations of mechanisms from one industry to another. Much of the belt conveyor practice of handling coke came from experience with belt conveyors handling the very abrasive gold ores of the Rand in South Africa, and the abrasive finely-crushed sands of copper and zinc ores in Western America, and sand and gravel (concrete materials) plants. In like manner the designs of belts, conveyors, and special chutes and feeding devices, developed in the coke industry to avoid breakage of the large pieces of coke, were adapted almost without change to the beet sugar industry with great success, to handle beet roots into store without bruising. In this connection probably a considerable portion

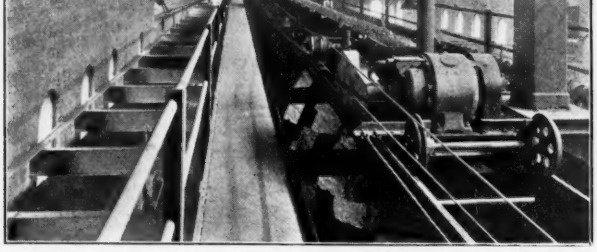


Fig. 4.—18 in. by 106 ft. Reversible Shuttle Belt Conveyor in a London Gas-Works—Installed in 1921.

of the attention given to the plant as a whole should be devoted to the chutes and other feeders which are described later.

As to the belt conveyor itself, great care should be taken that the supporting structure is strong, rigid, and straight when built, and that the tension in the belt is not too great. Belt tension is a matter of belt speed, belt thickness, design of driving mechanism, and slack take-up. If the belt is so tight or stiff that it will not settle, when empty, into a trough, and touch all the idler rollers, it will not run straight. The edges may be worn away, and atmospheric moisture getting through holes in the rubber will rot the cotton fabric of the belt. Also, spillage taking place, the coke will come in contact with the machinery. A hanging weight or hanging pulley take-up should be avoided, as they put maximum tension in the whole length of the belt, while tension should only be at its maximum immediately back of the drive, and become less and less along the length of the belt, until it becomes *nil* immediately before the drive. The pulleys around which the belt bends should have their diameters proportioned to the thickness of the belt, to avoid excessive bending stresses in the body of the belt. All journals on the conveyor, especially those of the idlers, should be grease lubricated, and large Stauffers used. No machinery can run without lubrication; but on coke conveyors an important function of the large grease Stauffers is to force the grease through and out to form a grease ring or collar round the shaft or spindle, where it enters the journal, to keep out coke dust. Plain journal bearings are recommended as most reliable and requiring least attention. Where a belt conveyor is so long that anti-friction bearings are necessary to reduce belt thickness, the roller bearing type is preferred, as the rollers have a line contact. Ball bearings are not recommended

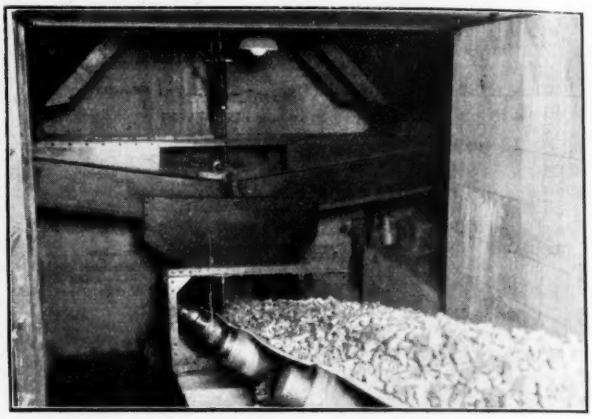


Fig. 5.—Double Displacement Feeder Discharging Coke from Two Hoppers and Fully Loading Belt Conveyor.

because of their point contact giving them a short life. In any case, even with anti-friction bearings, the Stauffer grease lubrication with its grease collar is necessary. Heavy cast-iron pulleys with crowned faces, protected screw take-ups, correct location of snub and bend pulleys, and other details are also of importance.

The five-pulley, or five-shaft troughing idler replaced the original three-pulley idler about fifteen years ago, as its curve more nearly approximated the natural catenary, avoiding the acute bending caused by the three-pulley idler, which tended to split the belt lengthways. Side guide idlers are not used by this system, except for very narrow conveyors, as they are injurious

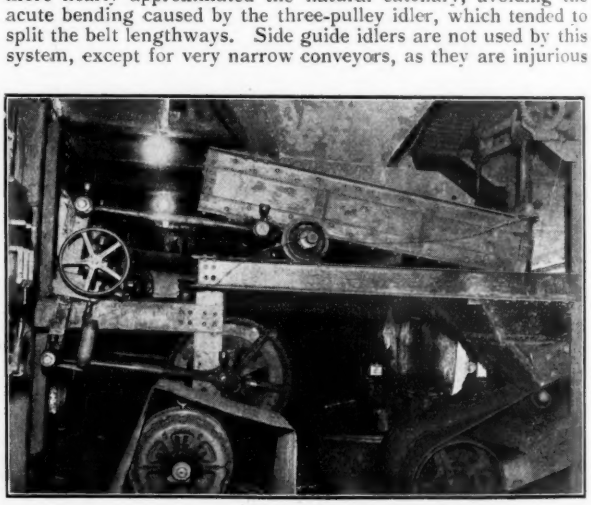


Fig. 6.—Single Displacement Feeder with Adjustable Speed, Stroke, and Inclination, Feeding Coke from Hopper to Belt Conveyor.

to the belt. The five-pulley troughing idler is now so made that, in connection with crowned faced main pulleys, proper chutes, &c., and a correct lining-up and levelling of the conveyor, the belt runs straight.

The belt conveyor is so well-known to be free from breakdowns that no spare conveyors are ever installed in a modern coke plant. There is no trouble that cannot be fixed in a very short time, if a few spare gears and pinions are at hand. A burnt-out motor is probably the worst thing that could happen; and this might occur on any other type of machine. Conveyor drives are generally connected by flanged coupling to a motor mounted on a cast base-plate; and, in a system of many conveyors, the drives are made duplicates where possible, so that a burnt-out motor may be immediately replaced by a fresh one. A belt is easily patched in place, and will operate and carry coke when almost in ribbons, while in the extraordinary event of a completely destroyed belt, a new one can be threaded in within 2 to 3 hours. The classic refutation of the moral in the old adage of danger when having all the eggs in one basket, at least where belt conveyors are concerned, is at a large London

power station, supplying electricity to the Underground Railway, where all the coal for this great station has been handled since 1904 by one belt conveyor with no alternate method.

Belt Cost Per Ton of Coke Carried.

It is difficult to give general figures, as conditions differ so greatly between installations. American works give a general figure for coal handling of 2d. per ton for the total operating and repair costs on large systems of belt conveyors. A few definite cases of British installations are given as more to the point. Other conditions being similar, the longer a belt conveyor is, the longer time a belt will last, as the principal wear

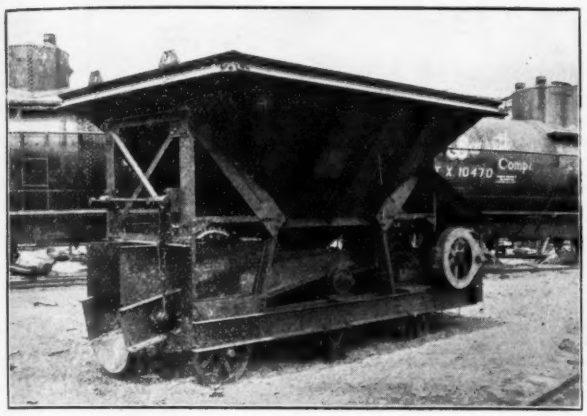


Fig. 7.—Travelling Reclaiming Hopper with Displacement Feeder to Feed Coke to Belt Conveyor when reclaimed from Store by Locomotive Crane and Grab.

is at the point the material is fed to the belt. Apart from the ordinary wear and tear, there must also be taken into account the burning of the belt when hot coke is carried.

A case with severe conditions exists in a London gas-works where a short belt conveyor was installed on Aug. 28, 1923, and handled very hot coke up to March 13, 1925, when the house was shut-down for alterations. This is a 24-in. shuttle belt conveyor 130 ft. long, receiving oversize coke from a rotary grizzly, and distributing it in a bunker twice the length of the conveyor. The coke is brought up to the grizzly by an inclined chain scraper conveyor from the quenching pit, and drag link conveyors in front of the retorts. The original belt carried 130,000 tons of coke during the 19 months' run, and at the shut-down it looked good enough to last another run of 19 months. This belt cost £197, and so far represents an expense of 0·364d. per ton of coke carried. By the end of another 19 months, if the belt is then worn out, the cost per ton may be

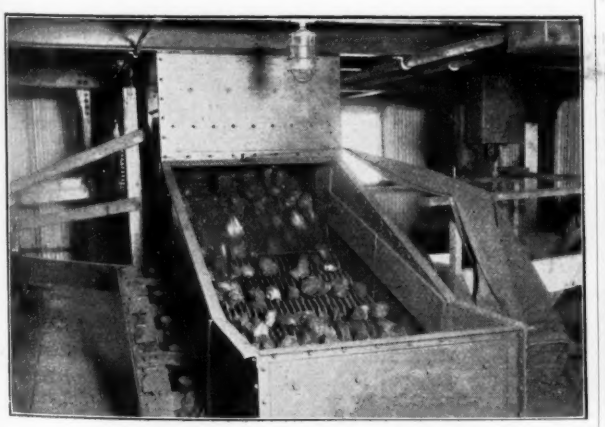


Fig. 8.—Rotary Grizzly in action Screening Coke.

The curious twisting motion given the pieces of coke is well shown.

expected to be in the neighbourhood of 0·182d. This conveyor needed a 5-h.p. motor for its operation, which included the shunting of the conveyor back and forth along the top of the bunker, as well as the running of the belt. With the exception of the few lower flat idlers to carry the return belt, which need replacing occasionally, the machinery receives no wear from the coke. During this run of 19 months the inclined chain scraper conveyor had its chain turned over once, then replaced by a new chain, at which time the guides on which the chain ran were also worn out, and had to be replaced.

At another London gas-works a 20-in. belt conveyor was put into operation in November, 1921, and for 3 years and 7 months has carried coke from a yard hopper to the water gas plant. This conveyor is 218 ft. long (fig. 3) and has a lift of 14 ft. It is fed from the hopper by an adjustable displacement feeder. The speed of the belt is sufficient to carry 20 tons of coke per hour. This belt has carried 46,000 tons of coke, and looks good enough for at least another 5 years. The total maintenance cost, wages, and materials of this conveyor, including motor and electrical equipment and the displacement feeder and its drive, was £24 4s. 2d. for the most expensive year, when some alterations were made. The average is about £20 per year. The power consumed is 2 kw., but we have no record of how many hours it has run. The belt cost £200; and if it is worn

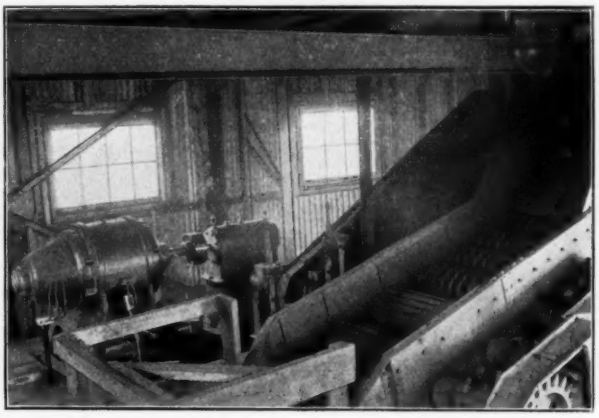


Fig. 9.—Combined Rotary Grizzly and Coke Breaker.

out after 8 years, the total expense, not including power, will be £360, or £45 per year, on a tonnage of 12,800 per year, or 0·85d. per ton—the belt replacement cost being 0·47d. per ton.

Feeding.

In this system the question of feeders is considered carefully. The endeavour is at all times to handle the coke as gently as possible in order to avoid breakage, to avoid making breeze, and to avoid wear and tear on the machinery used. Eliminating velocity is very important. Velocity causes wear to both coke and chute; and the checking of velocity after a slide or drop causes both breakage of coke and wear and tear of plant. Furthermore, careful feeding at a uniform and adjustable rate not only fills the conveyors full (fig. 5), so that the wear on them is the least per ton handled, but adds remarkably to the screening efficiency. Any screen works best with uniform steady feed; and with a proper feeder in the system, the stream of coke may be adjusted and controlled to the exact capacity which will give the screens the greatest efficiency.

Roll Feeder.

Fig. 2 shows a typical installation in which the coke is fed

Fig. 10.—"Perfex" Screen working at a London Gas-Works since March, 1923.

from a cooling bench to a belt conveyor. When a section of finger gate is raised, the coke slides down the bench and is carried forward at a uniform rate by the roll feeders, and deposited on the rubber belt with a very short drop and minimum breakage. As the roll feeders were revolving when this photograph was taken, the deep pockets in the rolls, in which the coke is carried forward, cannot be seen.

Fig. 11 shows an adaptation of this feeder to a travelling car to move along the face of the bench. Roll feeders are also used as velocity retarders in chutes from bunkers, and in chutes feeding screens and crushers, to give a uniform flow of coke.

Displacement Feeder.

This feeder is a development of the old jigging feeder or

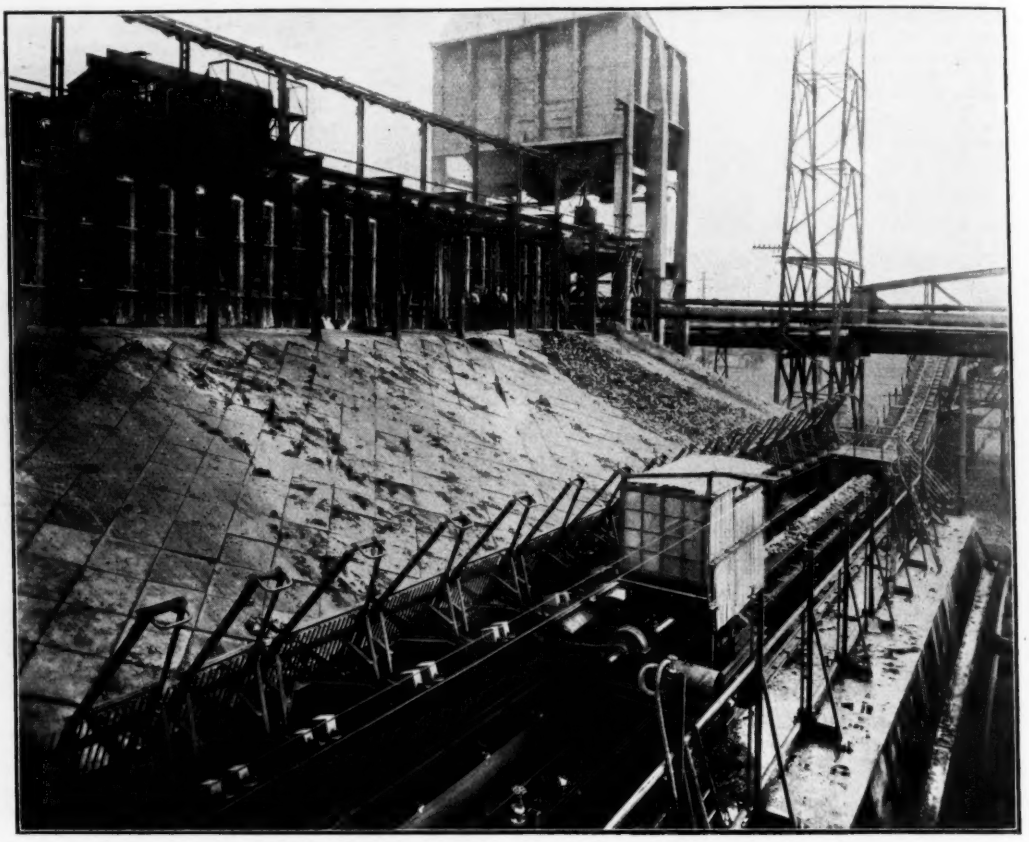


FIG. 11.—TRAVELLING ROLL FEEDER CAR DISCHARGING COKE FROM BENCH TO BELT CONVEYOR AT A BYE-PRODUCT COKE WORKS IN THE MIDLANDS.

shaking pan. It is principally used to feed coke from a bunker or hopper to avoid breakage of coke, to give uniform flow, or both. It consists of an inclined pan or chute, the back end of which rests on wheels, the front end being hung from adjustable rocking levers or adjustable swinging rods. A horizontal forward and backward motion is given by eccentrics or crank discs. The speed, length of throw, and inclination of pan are all adjustable, to suit conditions.

The principal feature of its operation lies in the fact that the throat opening of the bunker or hopper is very large, thus avoiding arching of the coke above the opening, and affording easy flow through. The coke comes to rest in the pan of the feeder, and forms its own angle of repose. The pan is made a little longer than this angle. As the pan is moved back, the coke drops-off the end, and a new supply comes from the hopper, spreading out as the pan moves forward. The feeder is its own gate or valve; and seldom is any auxiliary gate used.

In addition to overcoming choking in the hopper, and the exactly adjustable uniform feed it gives, the end of the pan may be brought so close to a belt that the coke has a very small drop to the conveyor. This type of feeder was developed in iron ore work, where it is necessary to feed great heavy jagged chunks of ore to belt conveyors. At one colliery the separated slate in sharp jagged pieces as large as 12 in. thick by 24 in. wide by 4 ft. long are fed to a belt conveyor, with little wear, by a displacement feeder at the rate of 1000 tons per hour.

Fig. 6 shows one type of single feeder, and fig. 5 a double feeder loading a belt conveyor evenly and fully from two hoppers. This type of feeder is often used for large material instead of a roll feeder, to give a uniform flow of material from a hopper to a crusher or screen, to increase capacity. They are often installed with their own hoppers on travelling carriages to run along a conveyor in a tunnel or underneath a bunker feeding the belt from any point, or to feed coke to a reclaiming belt; the coke being delivered to the hopper by a grab from the store pile (fig. 7).

Conveyor Chutes.

The chutes feeding to and discharging from a conveyor are, as already pointed out, important parts of the general design. The problem of head room is all important in designing a perfect chute, and many times the conveyor designer is not called in until after the locations and elevations of the parts of the plant have been established, to the great detriment of later maintenance costs, as faulty chutes have been fitted, because proper head room has not been allowed.

In this system the aim at all times is to prevent the coke having any velocity of its own, as velocity must be checked somewhere, sometime; and then there is coke breakage and wear of plant. In transporting coke there must be speed, but that speed should at all times be a carrying speed, and not a free running velocity. The function of a chute is to carry the coke at the same speed at which it is received, and deliver it at that speed to the next carrier. A chute should not only deliver coke to a conveyor at as nearly as possible the same speed as the conveyor is travelling, but should feed the coke to the centre of the belt, and fill the belt as full as possible, with the smaller pieces of coke on the belt first, and the larger pieces on top. The "V" plate chutes of this system fulfil these conditions to a surprising degree, and have greatly prolonged belt life.

Travelling Chutes.

To take coke from a state of rest, as in a bunker or hopper, and bring it up to the speed of a conveyor, at a uniform volume, with minimum breakage, is a big problem. In this system the roll feeder or displacement feeder is recommended; but they require power, and in some locations the use of power and power-driven machines is not advisable. In reclaiming coke from any valve of a long bunker or at any point in a long tunnel to a conveyor beneath, the electric wiring of the whole length is expensive. Internal combustion engines are sometimes used, but they vitiate the atmosphere in a confined space. The type of hand-travelled chutes shown in figs. 12 and 13 are often used. The angles and shape of the chutes to give smoothness of flow have been determined for each class of material by experiments in the field.

Telescopic Chutes.

This chute, shown in fig. 18, is used to mitigate as much as possible an unavoidable straight drop of coke. Where a boom-loading conveyor cannot reach the bottom of the drop, and a spiral chute cannot be utilized, this chute does help considerably. It is built like a telescope, suspended by the small end, with the large end down. The loading conveyor discharges into it, and the first coke falls to the bottom. The lowest section is on the ship's bottom, and the chute soon fills. The observer, above, seeing the coke is filling almost to the top, operates a hand or power winch that slowly lifts the lowest section of the chute. He tries to keep the surface of the coke as high as possible in the chute, letting it out at the bottom no faster than it enters at the top. When the lowest section has telescoped its full length, it raises the next section, and so on. There is a steady column of coke moving, not falling, through the tube, and a cone of coke gradually forming at the bottom. The coke emerging from the bottom of the chute rolls down this cone with little breakage.

Spiral Chutes.

These are the well-known chutes used at collieries for filling

bunkers. New inclinations have been determined by experiments to suit different kinds and grades of coke.

SCREENING.

Attention is concentrated on the different oversizes to be made, to see that they are clean of breeze, free from any coke of smaller size, and that when secured they are handled carefully to avoid breakage. The oversize is concentrated on for two main reasons: First, because as a rule the larger the coke the better the price obtainable; and, secondly, because generally the larger the size of the coke the greater its proportion of the whole, and each time a large size is eliminated from the mass the volume to be handled at the next step is correspondingly

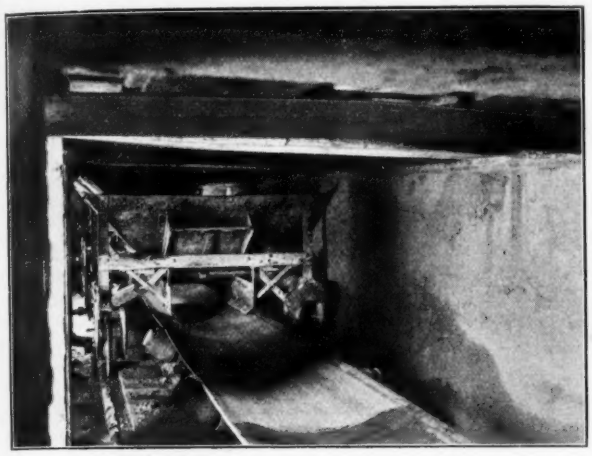


Fig. 12.—Low Reclaiming Tunnel under Store Pile, with Slide Valves in Roof and Low Travelling Chute for Feeding Coke to Belt Conveyor.

reduced. When large coke is passed over a fine screen it causes great wear both to the screening medium and to the coke. In this system the largest coke is removed first, then the next largest size required, and so on to the final screening operation which separates the breeze from the smallest size of coke required.

The greatest economy is obtained when only one screening station is used for an entire works, and the coke from all the batteries of ovens or from all the retort houses is brought to the central screening station for treatment. At a central screening station both the workmen and machinery work to the highest efficiency. The men do so because with a central station the tonnage handled is large enough to warrant detailing men to this work only, who, having plenty to do, with no other different duties, become very proficient as a result of specialization. The machinery does so because it is working all the time, no

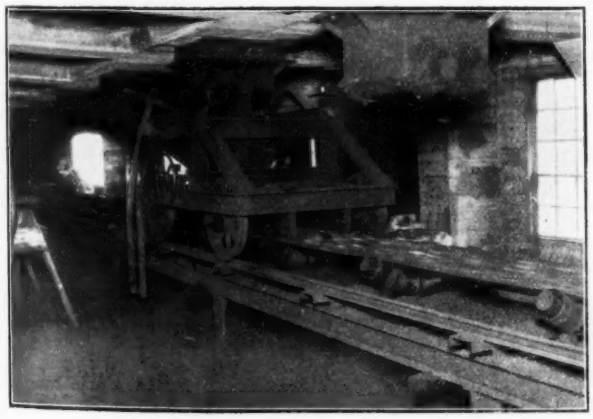


Fig. 13.—Travelling Feeder Discharging Coke from Overhead Valve to Belt Conveyor beneath.

The levers for opening and closing the valves are on the travelling feeder, so that a valve cannot be opened unless the feeder is in position beneath.

matter which retort house may be shut down, can be operated at the rated, and most efficient, capacity at all times, and is under the care of specialists.

The capital cost of a large central station is less than that of several small stations; and with a central station built in duplicate sections, one section can be a spare in the off season, and the feed switched from one to another while all are kept in the best working condition. This station may be located at some distance from the retort houses in such a position that it is near the store pile; and the shipping dock, roads, and tracks may be arranged for the most efficient handling, and not interfere with the gas and coke making.

The coke received from cooling benches, retort houses, bunkers, store, or any other source is carried by belt conveyor to the central screening station, where the conveyor discharges

Fig. 14.—1600-Ton Self-Unloading Coke Barge.

There are two belt conveyors running the length of the barge underneath the coke, discharging to a gross conveyor at the far end, the raising and lowering end of which may be seen. These belts unload the barge in five hours.

to one or more sections, each beginning with a rotary grizzly. This machine removes the largest size of coke required, and passes the throughs to the second screening unit. This screen, usually a finer screening rotary grizzly, or a balanced screen, removes the next largest size, and passes the throughs to the third screen. This is continued until, at the last unit, a balanced screen, the breeze is separated from the smallest size of coke required.

The first screening unit eliminates the greater part of the coke, the largest size, from the plant. The second unit eliminates the greater part of the coke it receives, and, as the coke progresses to the final breeze separation, the quantity to be handled grows less with each step until, at last, the screen with the finest mesh has the least to do of all.

Rotary Grizzly.

This machine is a high capacity, heavy duty, coarse screening unit. Its development was due to the need of a screen which, while small in size, would have a high capacity, small power consumption, and would not break the large pieces passing over it. The old bar grizzlies, owing to small capacity, frequent choking, and constant attention required, were generally superseded by the revolving screen (barrel screen or

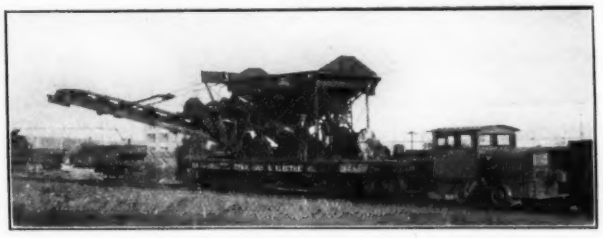


Fig. 15.—Coke Taxi.

Used for storing and reclaiming coke at a distance.

trommel); but this was found to have disadvantages, chief among which are small capacity for the amount of space and power required, and also because of the great amount of wear and tear both to coke and screen plates.

As shown in the photograph (fig. 8) this machine consists of a series of shafts set on a cast-iron base; discs being mounted on these shafts. A screening surface is formed by the discs, which are arranged and shaped to afford a large number of openings the exact size of the desired separation. The shafts are power driven. The driven shaft transmits its power to each of the other shafts by motor-car chain and sprocket drive. Side plates are provided to prevent the coke falling off the sides

of the grizzly, and the chains are covered by a guard. The screening surface is at an angle. The shafts revolve in the direction of the flow, and are driven at different speeds. From top to bottom the speed of each shaft is slightly faster than that of the shaft just behind it. This construction, together with the angle at which the grizzly is set, keeps all the openings clear. The oversize is carried forward over the grizzly at a uniform rate, the pieces being turned over and over, all the fine material is shaken-off and filters through the stream of coke until it reaches the holes, through which it drops, if of the proper size.

The rotary grizzly is used in three standard sizes. The coarsest has five shafts fitted with 18 in. diameter discs, and

Fig. 16.—"Perfex" Screens at each Bunker Discharge Valve, giving Domestic Coke as Final Screening as it is Loaded into Lorries.

will screen from 2½ in. to 4 in. inclusive, handling from 75 to 150 tons of coke per hour at these sizes. The medium has five shafts, and screens from 1½ in. to 2½ in. inclusive, handling the same capacities at these sizes. The finest has eight shafts fitted with 9 in. diameter discs, and screens from ¾ in. to 1½ in. inclusive at the same capacities. If accurate screening is not necessary, and these machines are used for "scalping," the capacities are greatly increased.

It has been found by experience that the conditions and requirements in Great Britain necessitate a somewhat different use of these machines from that common in America. Where the output of coke is less than 50 tons per hour, a grizzly is not

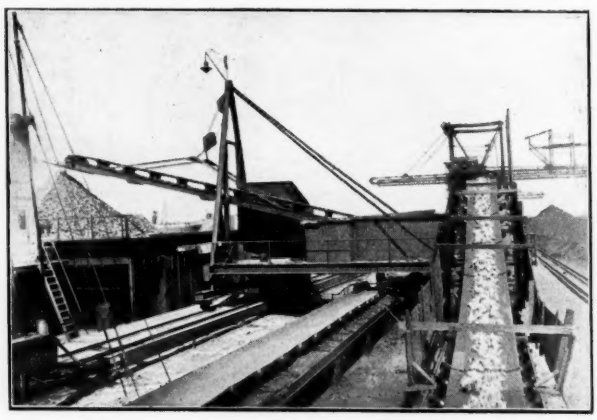


Fig. 17.—Ship Loading of Coke at Gas-Works.

The belt conveyor runs along the dock, and its travelling tripper discharges at a point to the travelling boom conveyor, which moves from hatch to hatch of a ship or along the length of a barge, making the moving of the vessel unnecessary. The boom conveyor is raised or lowered to give minimum drop to the coke.

necessary, as will be explained later under "balanced screen." Also, as it is difficult to change the screening size of a rotary grizzly, these machines should only be used where the screening is unlikely to be altered. In such other cases, where the sizing may be changed, it is a good custom to use the grizzly as a "scalper," taking out a large oversize, and sending the throughs to a balanced screen, on which the screen plate may be changed easily. The oversizes of the grizzly and screen are then joined together, to make one product (fig. 21). This arrangement makes full use of the grizzly as a high capacity unit, and greatly reduces the amount of feed to the grading screen, while making it possible to change the size of grading on short notice.

It has been found advisable in British practice not to run the run-of-oven or run-of-retort coke, containing the largest pieces, over the finer screening rotary grizzlies with 9 in. discs, as this causes too much wear on these small discs. This practice is common in America, with no complaints of undue wear—perhaps due, as suggested, to American coke being softer than British coke. On this account, in British practice, the 9 in. disc grizzly, screening down to ¾ in., is used only as a secondary screen after the large coke has been previously removed. For "scalping" or coarse screening, the grizzlies with 15 in. or 18 in. discs, taking out over 2 in., do not show any undue wear even on the largest and hardest coke.

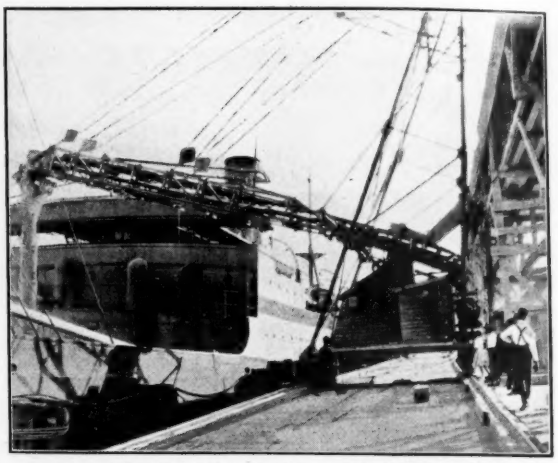


Fig. 18.—View of Travelling Loading Tower showing the Anti-Breakage Telescopic Chute on the end of the Boom Conveyor.

The combination of breaker and rotary grizzly shown in fig. 9 is very useful in some cases, especially where the output is often changed back and forth between domestic coke and furnace coke. The two crushing rolls are built-in as a part of the grizzly, and in making furnace coke all shafts revolve forward, sending the oversize over the end. The throwing over of clutches makes a last crushing roll revolve backward, and the oversize from the grizzly proper is crushed.

On account of the large capacity of the grizzly and its small size, the wearing action of a large stream of coke is concentrated on a small screening area. A five-shaft grizzly with 15 in. discs, grading to 2½ in., will efficiently screen 150 tons of coke per hour. This is done on a screening area 4 ft. wide by

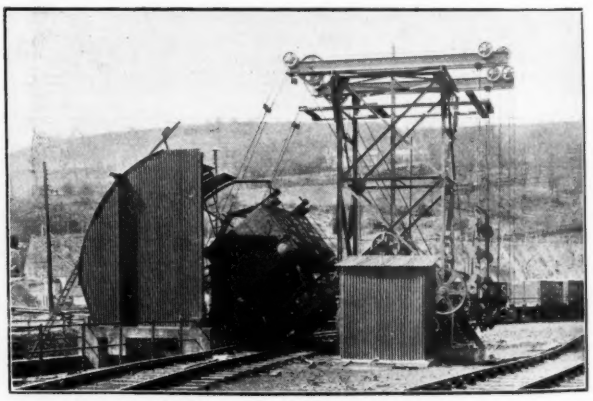


Fig. 19.—Truck Tippler Discharging Railway Trucks to Hopper Feeding Inclined Belt Conveyor.

5 ft. 8 in. long, or 23 sq. ft., giving it a capacity of 6 tons of coke per sq. ft. per hour. The greatest wear is on the first two or three shafts of discs; and for such an installation it is customary to have two spare shafts fitted with discs to drop-in in place of shafts on which the discs have been worn too small. The worn discs are then replaced by new ones, and these shafts held as spares.

A 7½-H.P. motor is sufficient to drive any of these standard grizzlies when handling their greatest capacity; a 5-H.P. motor generally being used for average conditions. It is difficult to make a general statement on the cost of wear and tear per ton of coke handled, as this lessens as the tonnage is increased. The greatest cost per ton occurs when a thin stream of coke is being screened and the wear is all confined to the centre of the grizzly. The average cost is when the stream of coke covers the width of the grizzly; and with this wide stream of coke the cost per ton grows less as the coke stream is made deeper, becoming least when the grizzly is handling its maximum.

A five-shaft 15 in. disc grizzly screening to 2 in. would handle 125 tons of coke per hour, but under average conditions it might receive only 75 tons per hour. Working half time on this capacity it would screen 900 tons of coke per day. Under such conditions, with the hardest coke, the discs would have to be renewed in from three to six months. If renewed in three months, the ones replaced would represent a charge of 0·7d. per ton on the coke handled during that period.

Balanced Screens.

The two balanced screens (sometimes called grasshopper screens), the " Perfex " (fig. 10) and " Roco," were developed to overcome the long-standing objections against the old types of reciprocating, impact, vibrating, jigging, and revolving or trommel screens, in coke plants. The slowly moving reciprocating screen was developed to handle coal; the trommel for stone, sand, and gravel; and the vibrating, impact, and jigging screens for very fine screening of ores in metallurgical plants. All of these have been used on coke with little or no adaptations to suit this very special material.

The coal screens did not have the liveliness or " kick " necessary to shake-off damp breeze from large coke; and also, for the same reason, the holes clogged. The trommel occupied too much space and used too much power in proportion to its small capacity, and crushed the coke too much. As a matter of fact, the " Bradford " breaker, the high capacity crusher so widely used in America for coal crushing, is a sort of glorified trommel or revolving screen.

The jigging, vibrating, and impact screens necessitated very strong, heavy supports, and shook themselves to pieces, aided by the emery-like abrasive action of the coke dust on their many friction surfaces.

The balanced screens were developed in coke plants. They are free from vibration, have a large capacity with small power consumption, give effective screening on every square inch of plate surface, and are rugged and simple in construction. The screening surface is flat, may be of punched plate or wire mesh of standard size, and is easily and quickly changed. The screen plate is attached by short-throw eccentrics to a cross shaft or shafts which are revolved at high speed. This causes the screen plate to travel in a circular orbit. The shafts are held in bearings attached to a cast-iron frame; and on the outer ends of the shafts are balance wheels counterweighted in opposition to the eccentrics. This counterbalancing absorbs the vibrating forces of the screen within itself, so that no strains are transmitted to the structure other than the weight of the screen and the pull of the belt.

The " Perfex " screen has two of these shafts connected by a roller chain transmission. It is a " fine " screen taking out from ½ in. to 1½ in. inclusive, and will handle from 15 to 40 tons per hour screening these sizes. The " Roco " screen is a coarser screen, taking out from 1 in. to 3 in., and will handle from 25 to 50 tons per hour. The " Roco " has one shaft only above the screen plate. The two eccentrics are fitted with Hyatt roller bearings, and the motion and inclination of the screen may be altered by changing the position of a pivoted arm.

Both screens may be fitted with two screen plates, one above the other, making them double-decked; and so each may make three products. This is sometimes advisable even when only one separation is required, as the upper deck, with large holes, will eliminate the large coke, leaving a much smaller amount to be dealt with by the lower deck, which can do the accurate sizing.

The " Roco " screen is often used instead of a rotary grizzly where the amount to be screened is not over 50 tons per hour.

ELEVATING.

Belt Conveyor.

The most economical method of elevating coke is by an inclined belt conveyor; but in many cases there is not enough horizontal room available. In other cases the amount of coke to be elevated is so small that the capital cost of installing an inclined belt conveyor is not warranted. As it is not advisable to run a belt conveyor at a greater inclination than 18° when carrying large pieces of coke, since the large pieces may roll back at a greater angle, the horizontal distance required to get a vertical lift is as 3 to 1. With small coke and breeze, a greater angle may be used; but the horizontal distance is still very much out of proportion.

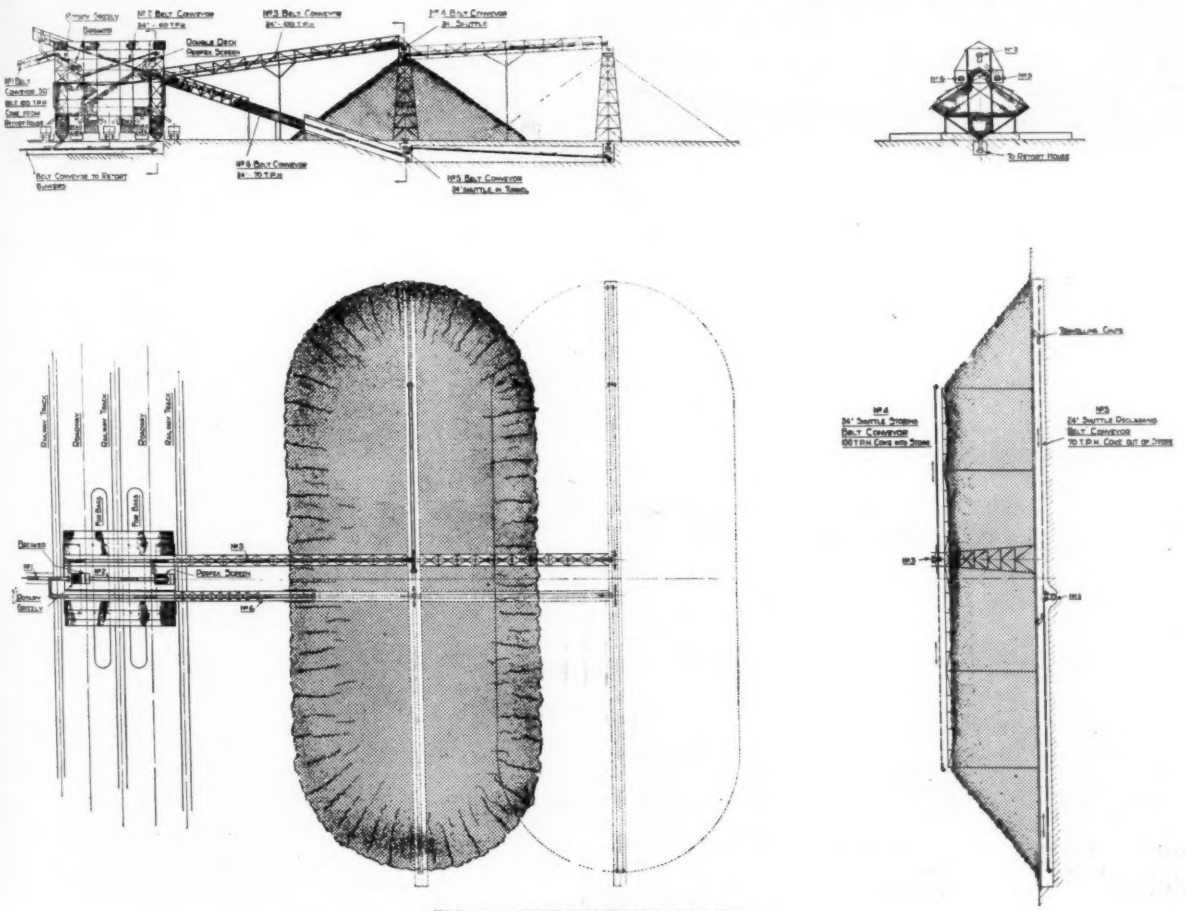


FIG. 20.—COKE-HANDLING PLANT.

Grab Hoist.

When material is to be taken from an ordinary barge or ship, a grab is about the only means; and once the material is in the grab the most economical means of elevating it is to keep it in the grab until it reaches the necessary height. In America the high-speed hoisting tower known as the " Boston " or " Steeple " tower, also the " Mast and Gaff " rig, are often used to grab coke from a vessel and raise it to a hopper feeding a horizontal belt conveyor, while on the Continent cranes and

transporters are often used. These installations are often used to bring bye-product coke into a water gas works. Breakage of coke, which to some extent is inevitable by grabbing, is undesirable; and this system does not recommend it except where other considerations have greater weight.

Self-Unloading Coke Barge.

A Steel Company solved the problem of barge unloading in a unique manner. They had to ship 1200 tons of coke daily from one of their own plants a distance of 18 miles down a river, and deliver it to blast furnaces on the other side of the river. The estimate of cost for the necessary railway equipment was appalling, and they did not want to incur the breakage and loss of coke incidental to grabbing from barges.

The "Robins" system was applied, and the result was a self-unloading coke barge (fig. 14). Belt conveyors carry the coke from the cooling bench to the dock side where a rotary grizzly takes out the breeze. A boom loader loads the oversize into the barge. The barge is 45 ft. wide and 355 ft. long with 7 ft. draught, and holds 1600 tons of coke in hoppers running nearly its full length. There are two 36-in. belt conveyors running in the bottom of the barge under the hoppers, and these draw the coke from the hoppers, carrying it to one end of the barge, where the ends of the conveyors incline up to above deck level. There they discharge to a 48-in. cross conveyor with a raising and lowering outer end. The barge is taken to the steel works, the hinged conveyor is let down to register with the end of a conveyor on shore. Connection is made with an electric plug

Belt and Bucket Elevator.

Bucket elevators of any kind are not recommended for coke if there is an alternative, as the wear on the buckets is severe. The chain and bucket type of elevator is not an economical machine for coke, on account of the severe wear on the chain and sprockets from the abrasive dust. In copper ore mills where finely-ground sands mixed with water must be elevated, the belt and bucket elevator was developed as the most economical machine for vertical hoisting. In some extreme cases the bucket elevator must be used in coke plants, as there is not the horizontal room available for a belt conveyor, or the amount to be handled, often breeze, is a small quantity. In these cases a belt and bucket elevator is recommended. The buckets are bolted to a rubber belt which is very resistant to coke dust abrasion and which does not break, as a chain often does. As the belt becomes thin after long use it stretches (the stretch being taken up by screw take-ups), and even after this stretching begins the belt need not be changed for a year or more. Thus ample warning is given.

At a London gas-works are two belt and bucket elevators handling coke breeze and smalls to boiler house bunkers. The first one has been in operation twelve months; and the maintenance cost, wages, and materials during the first year has been £9 1s. 11d. This includes all lubrication, attention to motor and electrical equipment, &c., but does not include cost of power used (about 2 E.W.). The elevator is of the vertical, spaced buckets, centrifugal discharge type, with belt 12 in. wide

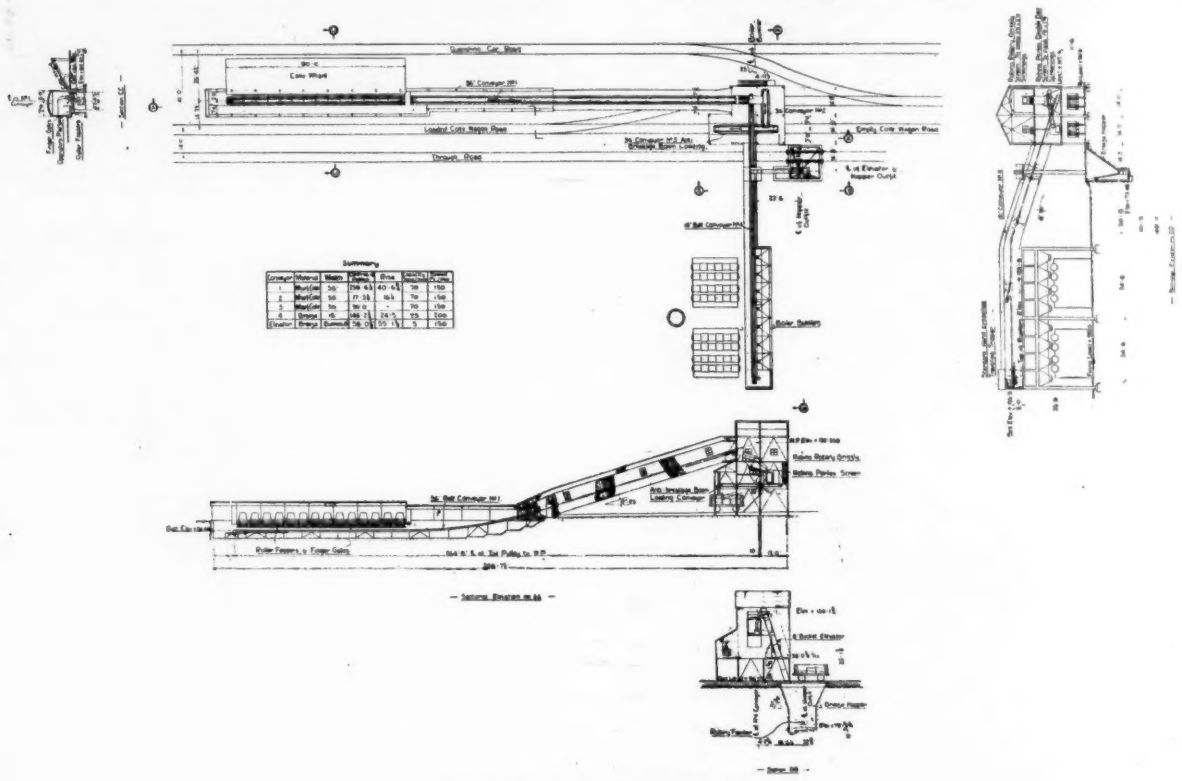


FIG. 21.—COKE-HANDLING PLANT.

socket on shore, and the conveyors unload the barge at the rate of 300 tons per hour to the shore conveyors, which carry the coke direct to the blast furnace bins. Such barges are, of course, not warranted unless there is a large and constant supply of coke to be delivered to a point not too far away.

Truck Hoist.

When coke is received at the works in 8 or 10 ton railway trucks which are not bottom dumping, and the number of trucks per day is not large, it is often advisable to instal a truck hoist to lift the loaded truck bodily to the required height, and there dump it into a hopper feeding a conveyor for distribution in the bunkers. There is considerable coke breakage when the truck is dumped, but sometimes conditions may in certain cases warrant this disability being suffered.

Skip Hoist.

This is an excellent means of elevating ashes, because the material handled does not come in contact with any of the machinery, but only with the skip bucket, the plates of which are easy to renew. From the same point of view the skip hoist is a good means of elevating coke; but from the point of view of the coke it is not as good, as there is considerable breakage at both ends. Where breakage is not of consequence, the skip hoist is recommended for coke.

and of a capacity of 20 tons of coke per hour. The vertical height between centres of pulleys is 53 ft. 6 in.

The second is of the same size and capacity but is 42 ft. 1 in. high. This elevator discharges to a 16-in. belt conveyor, with a travelling tripper, over the bunkers. This outfit has only been in operation a short time, and no costs are tabulated as yet.

BREAKING.

A works having an adjustable coke breaker and screens on which the sizing may be changed quickly is in a position to take advantage of any change in the market. The principal objection to breaking coke has been the percentage of breeze it makes. In some gas-works which use breeze to fire steam boilers, they are finding that they can make good use of more breeze than they produce. The growing development of pulverized fuel burning in power stations and metallurgical works is making another good commercial outlet for coke breeze. A certain percentage of coke breeze mixed with pulverized coal makes an excellent fuel, and this is a rapidly growing market. It would be a curious development if coke breeze, so long despised, became a valuable commercial product in the near future.

Even though the present conditions do not call for coke breaking, any new screening plants installed should be so designed that a breaker may be easily added if conditions change

in the future. The arrangements for the present or future installation of a breaker should be made in such a way that the breaker may easily cut into or out of the stream of coke. One good way is to instal the breaker so that the stream of coke may be by-passed underneath it if no breaking is required. This leaves the breaker open to inspection and free for repairs without interfering with production.

The capacity of a breaker is greatly increased and the wear and tear on it greatly decreased by installing a screen in front of it, to take out the same size the breaker is set to break. This also minimizes the production of breeze, as the coke, already small enough, is not subjected to any breaking action. When the market is such that the breaker must often be used, and yet there is occasionally a market for the very large coke, it is customary to use a combination of rotary grizzly and breaker—see fig. 9.

Many types of coke breakers are in use, and nearly all of them have their distinct fields of usefulness. For retort gas-coke breaking, this system recommends the two-roll adjustable fluted roll breaker preceded by a rotary grizzly or "Roco" screen. This machine is a true breaker, without any slashing or cutting action. The distance between the two rolls can be easily changed by screw adjustment, to get the exact product desired; and the percentage of coke smaller than the size desired is very small. The rolls are faced with horizontal flutes running parallel to the roll shaft; these greatly increasing the angle of nip, drawing the large pieces of coke into the breaking zone. The fluted periphery of each roll is made in removable segments of chilled cast iron, being fastened to the roll hubs by bolts with drop-forged steel heads, and may be changed at any time. The breaker is of very strong, rigid construction; and special attention was given in its development to having all parts accessible and easily replaced, and to interchangeability. These features have made it very popular with the repair men.

The heavily babbited bearings, which are split on 45°, placing the thrust directly on the centre rather than on the edges, are so designed for interchangeability that the halves may be turned end for end or completely reversed, thus greatly increasing their life. Removal of bearings is easily effected by jacking-up roll shaft 1 in., and removing cheek plates. The rear bearings rest against heavy steel coil springs, to allow the roll to give way in case any foreign substance enters the breaker; and the bearing support is arranged to insure alignment when the movable roll is forced back unevenly. Spring compression is adjusted by heavy set-screws. The steel shafts are of the same diameter throughout, so they may be replaced in the field without lathe work. The massive cast-iron side frames are tied together by cast-iron end pieces of channel section; and the housing and gear guards are of heavy mild-steel plate. No tap bolts are used, and all bolt heads and nuts are accessible. Stauffer grease cup lubrication is used throughout, making all bearings grit-proof.

The standard breaker is driven by belt to a fly-wheel pulley on the fixed roll shaft. The power is transmitted to the other roll through gears on the other side of the breaker.

An adjustable breaker is made for any amount of adjustable openings required between the rolls. The method of driving the movable roll by "toggle shaft" has been taken without alteration from the standard steel works practice of driving mill rolls.

STORING AND RECLAIMING.

Much thought, all over the world, has been given to this problem. As a rule some foreign system—*i.e.*, a system used in some other industry—has been used or adapted slightly. Where transportation is costly, a small gas-works in a secluded district may still man-handle its coke. However, with increasing competition due to the ability of large modern works, with economical handling systems making cheaper clean coke, to ship its coke widely afield, the question of economical handling is becoming urgent at small gas-works. As the standard of living all over the world rises steadily, the poorer classes demand more conveniences. The growing scarcity and higher wage of servants, due to the same cause, make it necessary for more middle-class families to resort to various contrivances to save labour in the home. Central heating is an important home labour-saving device, and is growing general, being helped in its speed by the efforts of many coke sales organizations, which will provide a home with some type of induced draught closed stove either free or on easy terms on condition of using their coke. In America the demand for domestic coke is greater than the supply of gas coke; and as bye-product coke can be burned in the anthracite coal stoves in general use, the bye-product coke producers are entering the domestic field so rapidly that the prices of blast furnace and foundry cokes are rising. To take full advantage of this excellent market, it is necessary to store coke during the summer; and the design of storage plants is important. Some coke is even being imported into America during winter seasons to supply the great demand. This trans-oceanic trade in coke is an interesting event, and, when the pendulum swings the other way, and the American market is over-supplied, the large coke producers of America

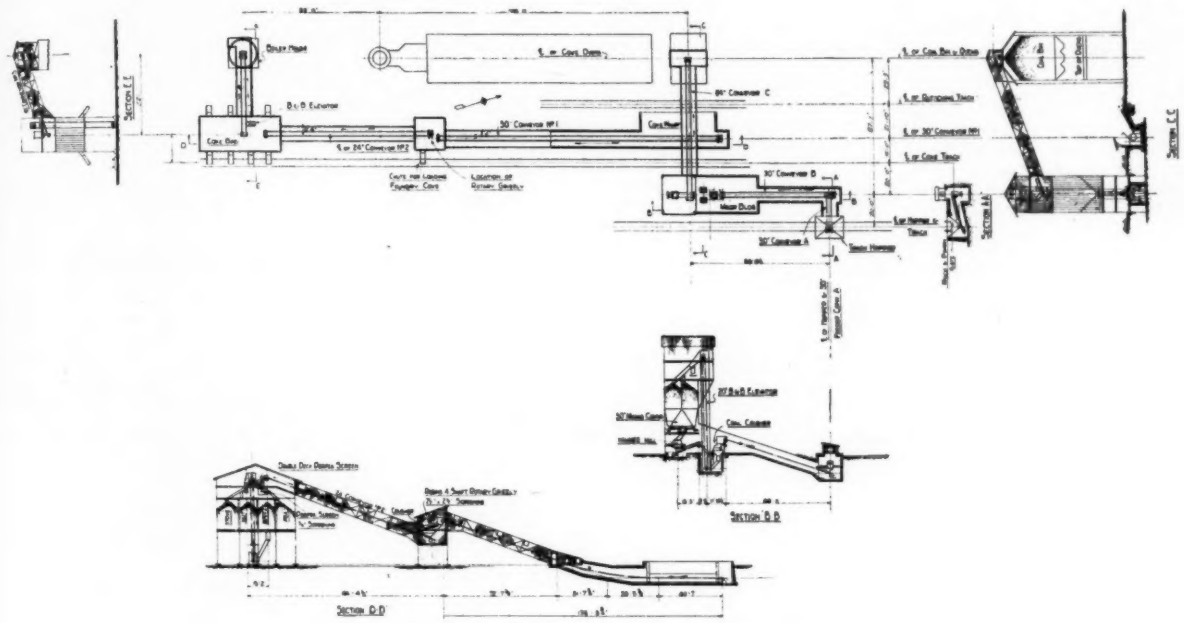


FIG. 22.—COAL AND COKE HANDLING PLANT.

COAL HANDLING SUMMARY.

30 in. feeder conveyor A.	Length, 20 ft. 2⅜ in.	Rise, 4 ft. 3 in.	Capacity, 75 T.P.H.
30 in. conveyor B.	Length, 71 ft. 5 5/16 in.	Rise, 22 ft. 2⅜ in.	Capacity, 75 T.P.H.
24 in. conveyor C.	Length, 92 ft. 8 7/16 in.	Rise, 31 ft. 8⅜ in.	Capacity, 75 T.P.H.
24 in. conveyor D.	Length, 15 ft. 5 in.	Rise, 4 ft. 8 in.	Capacity, 75 T.P.H.
30 in. mixing conveyors.	Length, 6 ft. 8 in.	Rise, 0 ft. 0 in.	Capacity, 75 T.P.H.
Two 20 in. B. & B. elevators.	Length, 72 ft. 1 in.	Rise, 72 ft. 1 in.	Capacity, 75 T.P.H.

COKE HANDLING SUMMARY.

30 in. conveyor No. 1.	Length, 183 ft. 3½ in.	Rise, 35 ft. 10⅜ in.	Capacity, 30 T.P.H.
24 in. conveyor No. 2.	Length, 112 ft. 7½ in.	Rise, 38 ft. 9 in.	Capacity, 30 T.P.H.
18 in. conveyor No. 3.	Length, 53 ft. 3 in.	Rise, 18 ft. 3 in.	Capacity, 25 T.P.H.
12 in. B. & B. elevator.	Length, 50 ft. 9 in.	Rise, 50 ft. 9 in.	Capacity, 30 T.P.H.

may look for markets abroad. Much British coke is shipped abroad, but this trade might be increased to such an extent as to compare favourably with the coal exports, leaving for home use, or export, the valuable bye-products of coal.

High quality, low costs, and quick delivery are necessary to capture any trade, whether home or export, or to build-up a new home market. British coke starts off with the advantage of high intrinsic quality, to which an additional high quality of grading and cleanness, combined with low costs and quick delivery, may be added by a works having an excellent system of central station screening and loading, and a good storage plant. Wherever possible the coke store should be a central one serving the complete works, and be connected to a central screening and crushing station with good facilities for fast loading into trucks, carts, and, if a tidewater works, into ships. Only unscreened coke should be stored, and this should be placed into store and withdrawn at high capacity, low cost, and least possible breakage. Some works have their store pile served by a transporter; but the grabbing of coke causes much breakage. The same objection applies to the reclaiming by locomotive crane to a conveyor. Bunker storage entails too much capital cost when done on a large scale, and is not flexible enough to take care of sudden slumps in the market. This system has developed a method of coke storing and reclaiming using shuttle belt conveyors and tunnels.

A typical plant is shown in fig. 20, working as follows. Unscreened coke is taken direct to the store pile from retort house or coke bench by No. 3 belt conveyor, which also takes to store any screening plant undersize not containing sizes suitable for immediate shipment. No. 3 conveyor carries the coke to the centre of a cross gantry, where it discharges to belt conveyor No. 4. The latter is a shuttle belt conveyor, a reversible conveyor mounted on wheels, and is half the length of the desired coke pile. The shuttle conveyor is motor driven and traversed. One man attends to the operation, moving it back and forth and reversing the direction of belt travel when necessary to deliver coke to any spot in the length of the pile (fig. 4). Storing begins at the end of a pile, and, to prevent breakage, the coke discharged from the end of the shuttle is lowered by a spiral chute. A conical pile is built, completely covering the spiral chute, until its apex reaches the top of the gantry. Then the shuttle is moved back a bit, and the fresh coke rolls down the initial cone. This is continued until the pile reaches the centre of the gantry. Then the shuttle is traversed back to the first half of the gantry, and storing continued to the far end with the belt of the shuttle running in the reverse direction.

A telescopic chute is sometimes used. It is removable, is kept at the centre of the gantry, and can be attached to either end of the conveyor as desired, and then travels with the shuttle to lower coke to any spot in the pile. Storing by conveyor in this way minimizes the breakage, but it has a slight segregating effect. The large coke is inclined to roll farther than the smalls, so that there is a greater proportion of smalls in the centre of the pile. Under the pile, in a tunnel, is conveyor No. 5, also a shuttle and a duplicate of No. 4 overhead. This conveyor works in two positions only, as shown, as it always discharges to conveyor No. 6 leading out from under the centre of the pile. The travelling chutes (figs. 12 and 13), which are not heavy, are pushed by hand to the proper valve openings in the tunnel roof, and the coke is easily reclaimed from the pile overhead. Conveyor No. 6 carries the coke back to the screening station, and discharges to conveyor No. 1 or direct to rotary grizzly. As different kinds of coke may be stored separately in the pile, or in separate piles, it is not necessary, when reclaiming coke that has already gone through the grizzly, to pass this coke over the grizzly again. It may be by-passed under the grizzly to the next unit.

When coke is stored in this way in a reclaiming tunnel, only half of it is reclaimable by gravity. The remaining half must be handled by grab, portable conveyor, or other means to the holes in the top of the tunnel. In some cases this is considered so important that sloping sides are built up to form a bunker bottom for the bottom of the pile, either of structure or banked earth, so that all coke stored will flow by gravity to the reclaiming tunnel. Generally, however, the pile is left as shown, and the outside coke is considered the last reserve of storage.

The tunnel conveyor system of reclaiming coke has been installed at works having other means of making the pile—such as railway trucks on gantries, aerial ropeways, cable car railways, telphers, portable conveyors, &c. A certain amount of breakage takes place with any method of piling; but by the use of the tunnel belt this is minimized while reclaiming.

In adapting this method to some small gas-works, and to some large ones where it is impossible to collect the coke from all houses for a central store, and where the conveyor to store cannot deliver to the centre of a shuttle gantry, the pile is formed end on to the retort house. This necessitates having both storing and reclaiming conveyors the full length of the pile. The overhead storing conveyor has a travelling tripper to discharge to the pile beneath, and the tunnel conveyor runs the full length of the pile. This design is quite good, though the tripper gives the belt more wear than a shuttle does. However, as the conveyors are twice as long for the same storage, it means more capital cost.

In some cases several piles are used, a by-pass chute being arranged at the end of No. 3 conveyor so that it may discharge either to the shuttle of the first pile, or to another conveyor leading to the shuttle of the next pile. This may be carried on to other piles in the same way. The reclaiming conveyors under the other piles would be joined up to a conveyor discharging to No. 6. The capacity into and out of store can be anything desired; the widths and speeds of the belt conveyors being made to suit.

A store pile made with one shuttle conveyor can be of great length, depending on the width of conveyor used. With a 24-in. belt conveyor as shown, the pile could easily be made 800 ft. long, as 24-in. shuttles 400 ft. long are in satisfactory operation. With such a storing conveyor mounted on a gantry 50 ft. high, the one store pile would contain 35,000 tons of coke. Often these store piles are started with a length of about 200 ft., room being left for extension, and the gantry and shuttles lengthened later as conditions warrant.

This method of storing and reclaiming coke is very economical. One attendant can, with only an occasional visit to the store, look after the storing and reclaiming, placing coke in store as fast as it comes, and reclaiming at whatever capacity the conveyors are designed for. The effect of the capital cost of such a storage plant on the cost per ton of coke would be greatest with a small store. A store of this type having a pile 200 ft. long would contain 9000 tons of coke. The capital cost of this plant, without the conveyors to and from the screening plant, amortized in ten years at 5 p.ct. would represent an annual charge of 9d. per ton of coke if the store was emptied and filled only once a year. This figure would lessen considerably if the length and capacity of the pile were increased. The maintenance and operating costs, including belt renewals, would average about £75 per year, or 2d. per ton of coke; and this would be the only cost after ten years when the plant had paid for itself. The reclaiming of coke from store by a tunnel underneath the pile ensures that the driest coke is taken from store first.

When the store pile is not covered, in a rainy or snowy country, high piles are maintained to have as much coke as possible in the interior of a pile protected from the weather, and often, when it is certain the coke will be in store for a considerable time, small coke and breeze are run out on the storing shuttle, and spread over the surface of the pile, as a protection against moisture and weathering.

When a pile is used as a balancing bunker, being drawn-on and filled often, a roof is sometimes built over it, supported in the centre by the shuttle gantry, and with roof principals inclining to the ground at each side of the pile.

Coke Taxi.

A rather novel method of storing and reclaiming coke at some American plants is shown in fig. 15. This is called a coke taxi. A standard railway platform truck is used on which the machinery is mounted. A large hopper feeds the coke to a belt feeder which discharges to a swinging boom conveyor. The whole affair is pulled about by a petrol locomotive on which is an electric dynamo connected by clutch to the petrol engine which also does the travelling. This dynamo is operated when the locomotive is standing still, and supplies current to operate the motors of the conveyors on the car. The taxi takes coke from the chutes of the coke bin, runs any distance to any part of the property, and the boom conveyor discharges to store pile on either side of the truck. A locomotive crane is used to grab coke from store to fill the hopper; the taxi then running back to discharge its coke to the coke bench, and so into the system again.

LOADING.

Market requirements differ so much that the method of coke loading to be adopted must be decided in each case by the local conditions. This system, however, is so flexible that it generally is able to meet the most exacting local requirements. The fundamental requirement is, of course, the delivery of clean, unbroken coke. Most American works have a raising and lowering boom belt conveyor to load the foundry coke in railway trucks with minimum breakage; but at the Canadian works shown in fig. 22 a chute is used. In like manner, at this works, the domestic coke is loaded by single chutes from the bins to railway trucks on one side, and to lorries and carts on the other side. The bagging of domestic coke is not general in America, and most of the coke is delivered in bulk. This makes the American domestic screening stations much simpler than the British.

Fig. 16 shows one of these two-sided American coke bins fitted with a "Perfex" screen at each loading chute, to give a final cleaning as the coke is loaded into lorries or carts. The requirements for foundry and blast-furnace coke are very exacting in America. "Foundry" is generally over 4 in. or over 4½ in., and must be quite clean. The custom is to use a rotary grizzly to take this large coke out of the system as soon as possible, so that the size of conveyors from that point on may be reduced. Foundry coke is generally loaded into trucks by a boom conveyor as soon as it has been separated by the grizzly.

Furnace coke practice has altered considerably in the past few years. It used to be "all over 1½ in." for furnace coke.

Now that blast furnace charge is sized, it is necessary to size the coke also. The rotary grizzly has added about 3 p.ct. to the furnace coke producing capacity of works, by giving a clean product down to ¾ in. Furnace coke is now *plus* ¾ in. *minus* 4½ in.; and if foundry coke is not being made, the oversize of the foundry grizzly is broken to bring it down to the maximum furnace size.

When the coke screening plant is near the furnaces the coke is carried by belt conveyor to the furnace bins; and lately there is a growing tendency to give furnace coke a final cleaning by running it over a ¾-in. grizzly just before it goes into the blast furnace skip.

Photographs 17 and 18 show a method of loading coke into barges and ships. Much bye-product coke is shipped by barge in America to water gas works, and much British coke is shipped abroad, especially to Scandinavia. Screened coke is taken direct from screening plant, or unscreened coke from store pile, and brought to the dock side by conveyor, or, if brought by trucks, the trucks are emptied into hoppers feeding the dock conveyor. Bottom dump trucks as used in the north of England and in America probably cause least breakage to coke. The end dump and the side dump tippler cause more breakage of coke, but the time saved by side dumping (fig. 19), which is very fast, as the trucks can be kept in a train and run right through the tippler, may offset some of the coke lost in breeze.

From the hopper the coke is fed with very little breakage, and at a uniform rate, to the conveyor by a displacement feeder; and this conveyor runs out to the dock side and along it, discharging at any point by a travelling hopper to a travelling loading tower (figs. 17 and 18) which can load the ship or barge without necessitating the moving of the vessel. A rotary grizzly is sometimes used to give a final cleaning to the coke before it is loaded. This may be installed on the travelling loading tower or on the dock conveyor, and is always noticed and commented on widely by the ship men, and gives the coke firm with such a loading plant much good advertising. On the end of the loading boom conveyor a telescopic anti-breakage chute is often used (see fig. 18).

TYPICAL INSTALLATIONS.

Gas-Works Plant.

As shown in illustration, fig. 20, quenched coke from the retort house is brought to the screen house on belt conveyor No. 1, which discharges either to the rotary grizzly, or, by throwing over a flopper gate, all the coke is by-passed to conveyor No. 3 outside the screen house, which carries to store.

The rotary grizzly (fig. 8) takes out the large coke, which either goes to the breaker or may be by-passed to the "large" section of the bin beneath. The chutes leading down into bins are often made spiral, to avoid breakage.

The throughs from the rotary grizzly, and also the broken coke from the breaker, are delivered by chute to No. 2 conveyor, which carries it the length of the building and discharges to the upper deck of a double-deck "Perfex" screen. This screen makes three sizes of coke—medium, small, and breeze—which are deposited in the bins beneath.

The mixed, unsized coke, at any stage of the process may be by-passed by chutes through the side of building to No. 3 conveyor and to store. This may be done with the throughs from the grizzly after the large has been taken out, or with the throughs from the top deck of the screen after the medium has been taken out. In this way, all the coke going to store is unscreened.

Three tracks and two roads run under the screen house for shipping coke. Three trucks may be loaded with large coke on one track, three trucks with medium coke on the centre track, and three with either small or breeze on the third track—all at the same time. While this is being done lorries or carts may be loaded with all sizes of coke in bulk on the two roadways, or bagged coke from the bagging platforms may be loaded on both road or railway vehicles. Coke may be taken direct from bins by conveyor No. 7 to retort house bunkers for fuel or packing.

Coke from store arrives on conveyor No. 6 and is discharged to No. 1, or direct to rotary grizzly. If the "large" bin is full, and small coke is required, the run-of-retort coke from store may be screened and crushed, or grizzly undersize may be brought from store, by-passed under the grizzly and breaker direct to conveyor No. 2 feeding the balanced screen.

The coke bins of the screening station shown have a total capacity of 600 tons. The design of this particular bin is quite special to suit the requirements. This station will handle 100 tons per hour of the coke it is designed for. The rotary grizzly takes 5 H.P., but does not have a separate motor, being driven from the head of the conveyor feeding it. No. 2 conveyor and the "Perfex" screen are driven together by an 8-H.P. motor, while the crusher takes a 25-H.P. motor.

This complete unit of screening and crushing plant, 600-ton bin, bagging and loading station, performs so many services that it is difficult to estimate the effect of its capital cost on the coke handled. By eliminating the bagging plant from consideration, the remaining plant will handle 100 tons of coke per hour. Considering this as working half-time, it would handle 1200 tons per day, or 432,000 tons per year. The capital cost of this plant, not including the storage conveyors, amortized in ten years at 5 p.ct., would represent 0·65d. per ton on the yearly cost of the coke.

If such a plant was to work full time, three shifts per day, it would handle 860,000 tons of coke per year. For this there should be a spare screening plant installed alongside the one shown. With the capital cost of this extension added, the total sum amortized in ten years at 5 p.ct. would represent a yearly charge of 0·4d. per ton on 860,000 tons per year.

The British coke handling plants built on the "Robins" system have not been in operation over five years, and none of the original belts has as yet been replaced, so no true complete maintenance costs have as yet been compiled.

At a typical American gas-works the total cost of handling coke with this system over a period of nine years is 45 cents (1s. 10d.) per ton. This cost includes amortization of capital, overhead charges, power, and all materials and wages of maintenance and operation. The output of this gas-works is 300 tons of coke per day, and the cost given covers all apparatus and labour connected with the coke from the time it is received unquenched from the vertical retorts by the quenching car until it is loaded into lorries for city delivery. The coke is handled by quenching car; cooling bench; a system of belt conveyors; storage plant; coarse breaking, screening, and loading station; domestic screening station with loading bins; and delivery of coke to retort bunkers by conveyor.

From the detail costs collected so far on individual units in Great Britain it is evident that the superior and less expensive British labour is giving costs considerably lower than the best American costs on the same type of plant.

Typical Bye-Product Plant.

Fig. 21 shows a plant for the Midlands. The cooling bench has fourteen roll feeder sections discharging to a 36-in. wide belt conveyor which handles 70 tons of coke per hour. This conveyor, No. 1, discharges to a rotary grizzly which eliminates all coke over 2½ in., this oversize going down a chute to 36-in. belt conveyor No. 2. The throughs from the rotary grizzly drop to the top deck of a double-deck "Perfex" screen having 1¾ in. holes. The oversize of this deck joins the grizzly oversize on No. 2 belt. The lower deck of the "Perfex" has ¾-in. holes, the oversize going down a chute to a truck beneath, and the undersize dropping to an 18-in. belt conveyor No. 4, which carries the breeze to the boiler-house bunkers. The large coke is discharged by belt No. 2, to a 36-in. conveyor No. 3, which is a hinged boom conveyor for loading into trucks with minimum breakage.

The breeze from another screening station at this works is brought by truck to a track hopper, from which it is raised by an elevator to conveyor No. 4 feeding the bunkers. This installation is quite flexible. The grizzly's only duty is that of "scalping," getting rid of the largest coke. The screen plates on the "Perfex" may be changed to get any sizes desired, or only one may be used, if less sizes are required.

Furnace Coke Plant in the Midlands.

Another such installation is an ordinary plant for making furnace coke; however, it has one unusual feature, the type of bench feeder used. The coke bench is directly in front of the ovens, and the coke is partly quenched in guides and partly on the bench. This gives a large quantity of water to be disposed of at the bench, which is not the case when a quenching car is used. It was necessary to set the belt conveyor away from the face of the bench, to allow space for a drainage trench. Standard finger gates are used, but roll feeders are not installed the whole length of the bench. As a rule, not more than two roll feeder sections are used at once, so two sections were mounted on a travelling car running along the face of the bench. The operator rides in this car and attends to all operations of finger gates, roll feeder running, and shifting of car, and has full control of feed of coke to the belt conveyor (see fig. 11).

A 30-in. belt conveyor carries the coke from bench to screening station, and delivers to an 8-shaft rotary grizzly with 9-in. discs, taking out all over 1½ in., which is discharged down a curved chute to the 30-in. belt conveyor for loading into trucks. The throughs from the grizzly drop on to an 18-in. belt conveyor which discharges to a single-deck "Perfex" screen. This separates the breeze and smalls, which are delivered by chutes to trucks on two rails beneath. In order to secure good screening it is imperative that the coke be fed to a screen at a uniform rate. This is achieved by the roll feeders at the coke bench, at the beginning of the system. At old oven plants where each battery of ovens has its own bench, and it is not practicable to change the quenching system and instal a central coke bench to serve all the batteries, when a new screening plant is desired, the roll feeder car, as illustrated here, is recommended as the least expensive method of applying the belt conveyor system.

One belt conveyor is installed in front of a line of coke benches, with one or two roll feeder cars to serve several benches. The existing gates on the front of the benches are retained, and no change made except to remove the chutes that used to deliver to trucks in front of the benches.

Small Canadian Bye-Product Works.

Fig. 22 shows a general arrangement of the material handling plant at a bye-product coke works in Hamilton, Ontario,

installed in 1924; and it may be of interest to follow the flow of material through it, to note the different conditions. Coal is dumped from bottom dump railway trucks into the track hopper, from which the 30-in. belt conveyor A carries it away at 25 T.P.H. (all the conveyors on this plant are working greatly under capacity, as they are arranged to suit future extension of plant and great increase in capacity) and discharges to belt conveyor B. Conveyor B delivers to a coal crusher, which reduces the coal to 1½ in., and then discharges to the boot of a 20-in. belt and bucket elevator which elevates to a height of 72 ft., where it falls into either of two 75-ton bins, one for each of the two kinds of coal used.

Under the bins are the two 30-in. mixing belt conveyors. These draw out from the bins the exact tonnage per hour from each, as predetermined. The adjustment may be changed quickly if there is a change in coal received. The coal falls into the hammer mill pulverizer, which reduces it to all under ⅛ in., and at the same time intimately mixes it. The 24-in. belt conveyor D then carries the coal to the boot of the same elevator which originally raised it, after crushing, to the bins. The elevator raises it again, but a flopper gate in the discharge chute being thrown over, the coal is now discharged to 24-in. belt conveyor C, which delivers it to the coal bin for feeding the ovens.

The quenched coke is slid on to the cooling bench (or wharf) by the quenching car, and is fed by standard roll feeders to 30-in. belt conveyor No. 1, which carries it up an incline to the foundry screening station, and discharges to a 4-shaft rotary grizzly with 2½-in. openings. This is a combination of grizzly and breaker. If foundry coke is to be made, it is eliminated from the system at this point by having both crusher rolls turn forward, passing the oversize to a chute loading into trucks on the track alongside. The throughs from the rotary grizzly and also the product of the breaker are carried by 24-in. belt conveyor No. 2 up to the domestic screening station.

Conveyor No. 1 is made 30 in. wide because of the size of pieces of coke coming from the bench. After the coke has been crushed, a smaller conveyor will easily handle the whole amount.

No. 2 conveyor delivers to a double-deck "Perfex" screen. The oversize from the top deck goes down a chute to the "stove" bin, the oversize from the lower deck goes down another chute to the "nut" bin, and the undersize drops to a single-deck "Perfex" screen which separates the "breeze" from the "pea," which drop into their respective bins.

Chutes from the sides of each bin load coke into railway trucks on one side or into lorries or carts on the other side. A chute from the bottom of the breeze bin loads a 12-in. belt and bucket elevator 51 ft. high, which discharges to 18-in. belt conveyor No. 3, carrying breeze to the boiler house bunker. The boot of the elevator is brought down to ground level, so that yard clean-up and any spillage may be disposed of by the elevator. The dredgings from the quenching sump are generally thrown on No. 1 conveyor and sent through the system, but are sometimes brought to the breeze elevator. All the belt conveyors and other machinery and plant are completely housed, owing to the icy winters, in order to protect the workmen and attendants. Two workmen normally attend to all the work of this handling plant. They dump the coal from the trucks, crush it, and fill the bins. They then throw over the required flopper gates and start the second part of the coal handling plant. The same men attend to the coke handling, one being stationed at the coke bench to feed No. 1 conveyor, and the other attending to the disposition of the sizes as made.

SECTION II.—COKE PREPARATION.—(*Continued.*)

Third Award, won by "Southron."

BY MR. S. E. WHITEHEAD, B.Sc.(ENG.), OF PORTSMOUTH.

It is admitted that there is much room for improvement in the character and quality of the coke produced at gas-works at the present time; and such improvement may be looked for in three main directions:

(*a*) *Chemically*	A reduction of the ash content of the coal carbonized.
(*b*) *Physically*	Such alterations in the methods of carbonization as will result in a harder, more uniform, and more openly-structured coke.
(*c*) *Mechanically*	More careful attention to the quenching and handling of the coke subsequent to its discharge from the retorts.

Item (*a*) is obvious. Item (*b*) is covered by Section 1 of the present Competition; but the fact must be recognized that, in general, any improvements effected in the physical characteristics will tend to simplify and render more efficient the subsequent handling and preparation. These improvements belong, however, to the future, and for the present purpose it is advisable to consider the subject of mechanical treatment (*c*) in its relation to the coke of to-day and to the conditions of its production now existing at the average gas-works. For the sake of brevity, general principles only will be indicated, and for the same reason the accompanying drawings are more or less diagrammatic.

The handling of coke may be said to commence at the retort mouthpiece and to end in the consumers' bags, wagons, or barges. It includes receiving the coke from the retort, conveying it to a suitable position, quenching, removal to store, screening, picking up from store, and finally delivering it into the wagon or other receptacle. Sometimes under the requirements of a specification or a local demand for graded coke, breaking must be resorted to before screening.

Bearing in mind that the customer requires a fuel of medium size, good colour, easily combustible, and as dry and free as possible from breeze and dust, it is obviously a comparatively easy mechanical problem to achieve something approaching perfection—but at a cost! The effort to produce a saleable commodity is founded upon a natural desire to increase revenue; and cost of production must always be a chief consideration—second only to the creation and maintenance of a market by the uniform high quality of the product.

The purpose of the present paper is to consider how best we may achieve the objects set out above, without unduly increasing the cost of the fuel to the consumer. That the coke account has an important place in the finances of a gas undertaking, even so far as to influence the price of gas, is clear when we remember that coke and breeze together represent approximately 23 p.ct. of the revenue obtained from the coal, and no less than 80 p.ct. of the value of the bye-products from that coal.

Discharging Coke from Retort.

Coke from vertical retorts, at any rate from those of the continuously-operated type, is commonly discharged already quenched—*i.e.*, at a temperature below ignition-point—into skips, which are then hoisted by telpher or crane, or upon a conveyor. Its subsequent treatment may be postponed until after the consideration of horizontal retort coke (together with that from intermittent verticals). In this case the charge leaves the retort at a high temperature under the influence of a ram or pusher. The ram discharger is the commonest type, and is the natural outcome of the heavy charge or packed retort—essential to economic working. Careful observations show that, for a given weight and density of charge, and *provided that the charge is fully carbonized*, the action of the ram is not deleterious to the final condition of the coke. "Green ends" will naturally suffer from the crushing effect of the pusher; but a well carbonized charge of coke will, when pushed out, emerge without appreciable fracture. In experiments carried out by the writer, charges of coke from Durham coal were found to bridge over a gap of up to 12 in. without fracture.

Receiving Hot Coke.

The transit of the coke from the mouthpiece is a source of considerable breakage and consequent financial loss, unless the dropping of the coke through any appreciable height is reduced to the absolute minimum, and sliding substituted at every point. For this reason any plant in which the carbonized charge is dropped directly on to a conveyor or into a telpher or other skip may be considered out-of-date. The ideal means of coke handling, from this point of view, is furnished by one of the transporter machines, such as the "G.N." or Drakes', where the coke slides from the retort into the transporter, and thence out upon a quenching bench, and finally into skips or on to a rubber belt—such an installation offering the minimum fall to the coke. The transporter is also fully justified on other grounds. In first cost it compares favourably with other methods; the outlay on machine, rails, quenching bench, &c., being very little more than is required, for example, for a "D.B." conveyor installation. There is also a great saving in wear and tear. Carefully prepared figures of an actual comparative case show the following maintenance per ton of coke handled:

"D.B." chain conveyors ... ... 6d.
"G.N." transporter ... ... 1½d.

It is, of course, not always practicable to instal such new plant; and where this is the case every effort should be made to guide the coke by means of shoots, &c., very little steeper than the friction angle, from the mouthpiece to the conveyor or skip.

Transporting Hot Coke.

For hot coke conveying a rubber belt is clearly inadmissible; and the forms of conveyor available—the drag bar (such as "D.B." or West's), the tipping tray, the push plate, &c.—are all open to very serious objections. First, they tend to the formation of a high proportion of breeze, particularly in those cases where the coke is dragged along a trough. Secondly, the wear and tear on such appliances is very high, owing to the abrasive action of the coke dust produced. Provided the before-mentioned requirements with regard to fall are satisfied, the ideal method of transporting hot coke is in a moving receptacle such as a skip, or the tube or bucket of a transporter machine. In such a case the actual transporting from place to place has no effect on the character of the coke. Telpher transport is frequently adopted for this purpose, but cannot be said to approach the ideal. The wear and tear on the skips is high, quenching difficulties—which will be noticed later—appear, and the system applied to hot coke is not practicable for any but the smaller retort houses, owing to the relatively slow speed, and consequent delay to the operation of the stoking machinery. Considerations of quenching (treated later) again point to the superiority of the transporter feeding a suitably-designed quenching bench.

Dumping the Coke.

Here again the advantage lies with a transporter—particularly one of the "G.N." type—for the hot coke is allowed to slide out at a gentle angle, under the best possible conditions to avoid breakage. A hot coke conveyor must of necessity drop the coke at some point, and frequently also a change of direction is necessary—for example, when coke is transferred from one conveyor to another running at right angles to it. Such an arrangement is certain to break-up the coke to a very serious extent, while tipping skips—and, to a smaller degree, bottom-discharge skips—also "drop" the coke more or less forcibly.

Quenching.

With the single exception of screening, the quenching of coke is probably the process which has most direct influence on its final quality and "saleability," and it is also an operation in which there is great room for improvement. Insufficient quenching is a source of fires in hoppers and coke heaps, which entail an increase in ash and breeze content, as well as the labour required to deal with them. On the other hand, excessive quenching results in sodden coke, heavy, and of bad colour—a fuel which destroys the consumer's confidence, for he finds it almost incombustible.

Dry quenching—as in the "Dryco" plant—gives at once a means of removing all possible objections to the coke on this score; and if the sensible heat of the coke can be utilized, as is effected in the Sulzer hot coke steam generator, the process is as nearly ideal as can be obtained. But these plants are almost prohibitive in cost. A high capital outlay is involved; and this in the majority of gas-works would probably debit the coke with such a high standing charge as would outweigh the advantages to be obtained.

Otherwise, the quenching of coke may be carried out in several ways, the principal of which are:

(*a*) Direct spraying on floor or in skip.
(*b*) Tank quenching, by immersion of the lower portion of the skip.
(*c*) Combined automatic spraying and immersion on conveyor.
(*d*) Steam quenching on special "quenching conveyor."
(*e*) Direct spraying on open bench.
(*f*) Steam quenching on enclosed bench.

Quenching probably presents a different problem on each individual works. It is influenced not only by such factors as volume and pressure of available water supply, but also by the size of the coke to be quenched. This in turn depends upon the

class of coal carbonized and upon the weight of charge and method of charging, as well as upon the treatment to which the fuel has been subjected since leaving the mouthpiece. For instance, Lancashire and some Yorkshire coals give a comparatively small and fairly hard coke; Durham coal gives a larger and hard coke; Somerset very large lumps of soft coke. These questions modify both the handling and quenching operations; but it may be said in general that pressure, rather than volume, of water is required, and that it is better to do as much as possible of the quenching by steam rather than wholly with water. This may be carried out either in an enclosed chamber, or, in a modified way, by bringing the water into contact with the bottom layers of a mass of hot coke, and allowing the ascending steam to assist in quenching—which is the principal reason for a high water pressure being advisable. In practice, water at 80 to 100 lbs. per sq. in. is found effective.

Returning to the various methods enumerated above, the objections to the first are the difficulty of avoiding either sodden coke on the one hand, or fires due to insufficient quenching on the other, and the high maintenance costs of the skips. Tank quenching also presents the latter objection, with the added disadvantage that the boiling of the water in contact with the skip scatters small pieces of coke and breeze over a considerable area. In a recently-erected installation it is sought to overcome, or at any rate to reduce, this difficulty by fitting hinged covers to the quenching tank, which doors are automatically closed by the telpher skip immediately before it touches the water. The only drawbacks to this scheme would appear to be cost, mechanical complication, and necessity for frequent cleaning out of the tank; but the device has yet to be tried out over a period.

In method (*c*) the coke is partly quenched in its travel along the conveyor by water sprays which are operated automatically by the coke itself, the process being completed by the passage of the coke through water lying in the trough, which is laid with a fall to the discharge end. This final quenching is found necessary in practice as the sprays alone are insufficient; but it also has, unless carefully regulated, the opposite and undesirable effect of soaking the coke.

The use of method (*d*) entails a special length of "quenching conveyor," which is commonly some 20 ft. of inclined "D.B." chain sealed by water or other means at the bottom, and having near the lower end some modified spraying device. The effect is to fill the conveyor casing with steam, which, by the exclusion of air, prevents the combustion of the coke, and, finally, by its cooling action, reduces it below ignition temperature. This obviously offers a means of thorough quenching, while avoiding as far as possible a high water content, but it cannot be considered good practice to introduce for this purpose a conveyor or other appliance which has the effect of making more breeze. It is also difficult to seal the intake end of the device satisfactorily. If this is not done, the quenching conveyor becomes a flue, the draught in which tends to fan the hot coke to a higher temperature.

The use of a quenching bench (*e*) eliminates many of the objections to the foregoing methods, and is, in fact, almost a necessity where modern hot coke transporters are in use. The general construction of the bench (fig. 1) is best carried out in ferro-concrete, the bench itself being paved with firebrick or Staffordshire bricks, either blue or preferably brindled. While these surfaces have proved satisfactory in this country, it is worthy of note that in Germany renewable cast-iron plates 1 in. thick are used on benches. An important point is the angle of slope, which varies slightly with the nature of the paving and with the water supply. If the available water pressure is low, it is advisable to give the bench only sufficient slope to cause the coke to slide. By this means the charge of coke leaving the transporter spreads out into a comparatively shallow layer. The angle in this case should be for brindled brick 32° with the horizontal, and about 30° to 32° for cast iron. The angle for other surfaces may be estimated from the following table of friction angles found in experiments carried out by the writer.

Coke Sliding Upon:	Friction Angle. ϕ.	Co-efficient of Friction. $\mu = \tan \phi$.
	Degs.	
Rusty mild-steel plate	28	0·53
Clean cast-iron plate	26	0·48
Black sheet iron	20	0·36
Firebrick	29	0·55
Concrete	27	0·51
Staffs. blue brick	26½	0·50
Staffs. brindled brick	27	0·51
Slate	28	0·54

If the water supply should be at a higher pressure—say, 80 lbs. per sq. in. or over—it appears advisable to use a steeper bench, in which case the coke slides more quickly and forms at the bottom gates a thicker layer, into which the water may easily be driven from suitable nozzles. The nozzles, which should be either ball-jointed, to permit of easy manipulation, or attached to a short length of hose, should be so mounted that they may be operated from a platform running parallel to and above the quenching bench. The bench is provided with suitable gates, &c., which are outside the scope of this paper; but it is important that its slope be so arranged that the coke will slide without any appreciable fall from transporter to bench, and with as little drop as possible from bench to skip or conveyor.

The quenching bench system as described above is very effective under normal conditions, but certain difficulties may be encountered, notably when very large coke has to be dealt with. In such cases a certain degree of breakage may have to be resorted to until the coke can be quenched satisfactorily, and its accompaniment of increased breeze and dust content borne. In any case the coke cannot normally be sold of very large size,

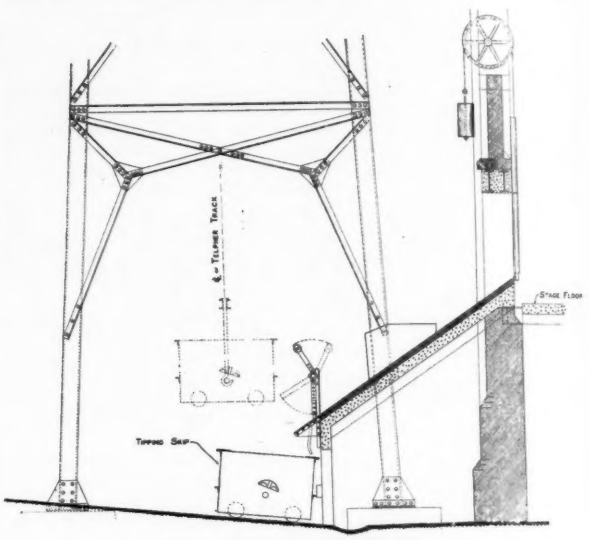


Fig. 1.—Open Quenching Bench.

and if it has to be broken for sale, it is more economical to carry out the breaking at an early stage, thus obtaining the full advantage in quenching. System (*f*), however, offers a partial solution, and probably represents the best means of quenching yet available for horizontal retort practice. In this case (see fig. 5) each bay of the quenching bench—usually corresponding with one bed of retorts—is covered with a steel casing and fitted at top and bottom with gates, which are, for all practical purposes, air-tight. After introduction of the coke, the doors are closed, water sprays turned on at the lower end, and the bulk of the quenching is effected by steam, the excess of which is led away through a steel flue or shaft in the top of the casing. It should be borne in mind that only an average of two charges per 2-hourly draw is discharged for quenching from each bed of retorts. The coke, therefore, may be allowed to remain for a considerable time in an atmosphere of steam, thus being very effectively quenched with the minimum amount of water and breakage.

Transporting Quenched Coke.

Having arrived at the point where quenched coke has to be dealt with, we may proceed to consider the further handling of the material from both horizontal and vertical retorts. Other things being equal, there is no doubt that the rubber band conveyor (see fig. 5) is the one practical means of conveying cold coke. Its first cost and power consumption are remarkably low, the life of the rubber belt is very long (up to 800,000 tons has been recorded), and the coke, since it remains practically stationary relative to the belt, is not subjected to rolling, churning, or grinding. In addition, all moving parts are out of contact with coke or breeze. There are obvious limitations to the use of a band conveyor, chiefly connected with direction, position, and angle of slope, which, of course, must be less than the friction angle. Though its use for hot coke is not possible, the belt conveyor will withstand damage from an occasional piece of hot coke to a surprising degree, and may further be treated, for example, with a layer of breeze and thick tar, to render it still more fireproof.

Next in point of importance comes the electric monorail telpher. The advantages of this machine are well known; one of the chief being the low expenditure on maintenance and running (in spite of a comparatively high first cost), owing to the fact that most of the capital expenditure is upon structure, and only a small proportion upon machinery. The system has, however, certain limitations which are not always fully recognized. It is obvious that the scope of such a machine is limited to an area having the track as a centre line, and width depending upon the tipping height of the plant. Moreover, the fact that only one machine can usefully operate on any one section of the track renders the telpher too slow for some purposes, particularly the removal and quenching of hot coke direct from a large house of horizontal retorts, discharged by up-to-date machinery. But in the cases of vertical retorts and of a quench-

ing bench, such as that now under consideration, a certain amount of storage is provided, either in the extractor chamber or on the bench itself, and the discharge of the coke is then rendered independent of the speed of the telpher transporter. The first cost of the plant is fairly high—depending upon the length of the track—but the maintenance and running costs are very low, each being in the neighbourhood of ½d. per ton handled for a large installation.

Since at this point in the operations it is usually necessary to elevate the coke to some considerable height, and since other available methods, such as "D.B." or other conveyors, entail breakage of the coke and high maintenance costs, no other system need be considered.

Storage.

In many instances, particularly in times of market depression such as the present, a large quantity of coke must be dumped upon the yard or coke heap; but in order to minimize double handling, this should always be regarded as a stand-by measure, current requirements being supplied from make via suitable storage hoppers or bunkers. The best material for the construction of these hoppers is undoubtedly ferro-concrete, which, though relatively more expensive to use than steel—in about the proportion of 11 to 10 at the present time—very soon pays for itself in reduced upkeep. The form and division of the hoppers depend entirely on local carbonizing conditions and market requirements, but in either method of construction the

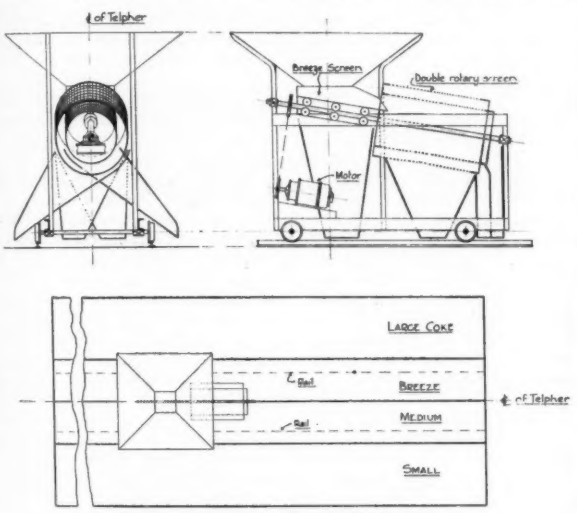


Fig. 2.—Diagram of Travelling Screen.

inner surfaces must be protected from the abrasive action of the coke. Steel hoppers should be fitted throughout with mild-steel or cast-iron lining plates, fitted with countersunk bolts in such a way as to be easily renewable, while those of concrete should be lined with 9 in. Staffordshire blue tiles, 2 in. thick, or with a rendering of special concrete made from furnace slag and cement. Hoppers are fitted with ample discharge openings and slides (see fig. 4) by means of which the supply of coke to screens, &c., can be easily regulated. The extended use of coke for domestic purposes lends more importance to the provision of suitable storage, since a demand for this purpose is a seasonable one. In such a case, the gas undertaking—particularly one situated in a purely residential district—would be called upon to stock a large proportion of its summer make until the autumn. When a bunker in (say) reinforced concrete costs nearly £10 per ton of capacity, and that bunker is only to be filled and emptied twice or three times in the year, it is clearly impossible to consider the provision of bunker-storage; and the apparently wasteful coke-heap in the yard seems the only practicable solution. Such a heap may be fed by crane or telpher, but both these machines are more costly to maintain and operate than a set of band conveyors running on a suitable structure and provided with throw-off carriages and shoots. The band conveyor in this case may be an extension of that feeding the hoppers or primary screens. It rarely pays to stock screened coke, on account of breakage and weathering. The

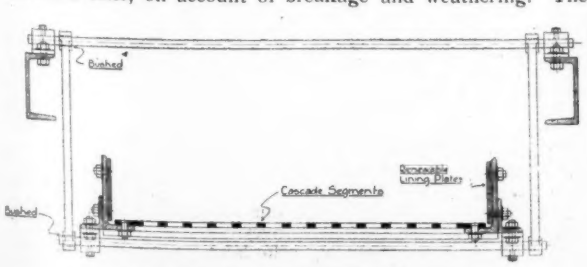


Fig. 3.—Section through Shaker Screen.

removal of coke from a heap must always be a rather costly business. Grabs worked from either telpher or loco-crane, or wagon loaders, such as Jeffreys', may be used, but these result in so much breakage, and are so costly to maintain, that the best method is probably hand-forking into skips or on to a portable band conveyor. If desired, however, the coke may be fed either mechanically or by hand into a portable screening plant—a good plan on the larger works, where such a machine can be kept fully employed—in order to avoid the costly hand-forking. In very large installations the coke should be taken from stock by grab or inclined band conveyor to screening plant over a second set of bunkers.

Depositing Coke into Store.

The aim here, again, must be to subject the coke to as little fall as possible; and what may be described as the "progressive" method should be adopted where possible. Two illustrations of this method are the "shuttle belt" and the "travelling screen." The former, shown in fig. 5, is a reversible band conveyor half as long as the hoppers and mounted on a carriage and rails, by which means it is fed with coke from the central receiving hopper or screen, and deposits it at any point on the centre line of the hoppers, which may be continuous or divided transversely. In the case of the travelling screen, which is shown diagrammatically in fig. 2, the hoppers must be divided longitudinally, and the screen, which is preferably fed from a telpher, runs on rails along the whole length. It consists of a shaking screen for breeze, and one or more rotary screens mounted on the same shaft and corresponding in number to the required grades. In each case the plant is arranged so that coke is never allowed to fall to the bottom of a hopper, but is always discharged upon the top of a sloping bank of coke. The advantages are obvious, and as near as possible an approach to this method should be secured when operating other types of plant—*e.g.*, a telpher skip should be lowered to the surface of the coke heap before being discharged; a band conveyor should be provided with a travelling throw-off carriage and shoot; and so on.

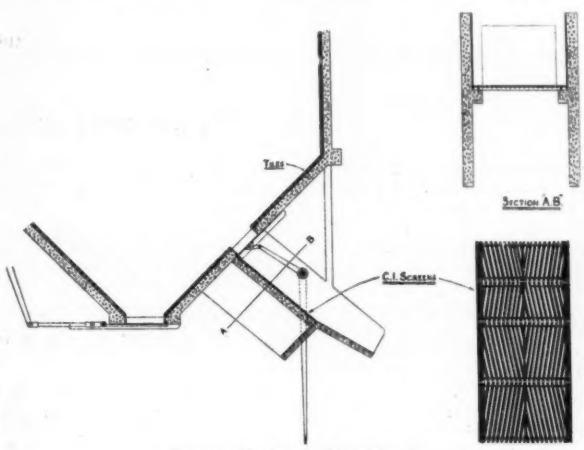


Fig. 4.—Stationary Bar Screen.

Cutting and Grading.

Coke cutting machines are inveterate "breeze makers," and should be avoided wherever local conditions allow. The additional quantity of fine breeze and dust made during cutting with average coke and a good type of cutter is 20 p.ct. In other words, out of every 100 tons of unscreened coke passed through the cutter, 20 tons of graded coke is lost as breeze. At present prices this represents a cost of 5s. per ton of finished coke; and as this product, after cutting and washing, is worth at the most 5s. per ton more than ordinary screened coke, there is clearly a serious loss. This is at least equal to the cost of cutting and washing, including labour, standing charges, power and maintenance costs; and, as may be expected, the wear and tear on a coke cutting plant is very high. When, however, a demand for various grades of small coke has to be met (as in London and other large industrial centres) this operation is necessary.

Grading or screening should obviously be performed as the last operation; and it is not too much to say that all coke sold should be screened immediately before it enters the customer's wagon or other receptacle. When, however, several grades of coke are sold, particularly under London conditions, it is necessary to introduce some form of preliminary grading into the hoppers, which must be suitably divided for the purpose.

Preliminary Screening.

The necessity for grading coke into storage reduces the capacity of the hoppers, or, alternatively, renders it necessary to elevate the unscreened coke to a considerable height. If this is no disadvantage, a central receiving hopper may be arranged to take the material and discharge it over a bar screen, which

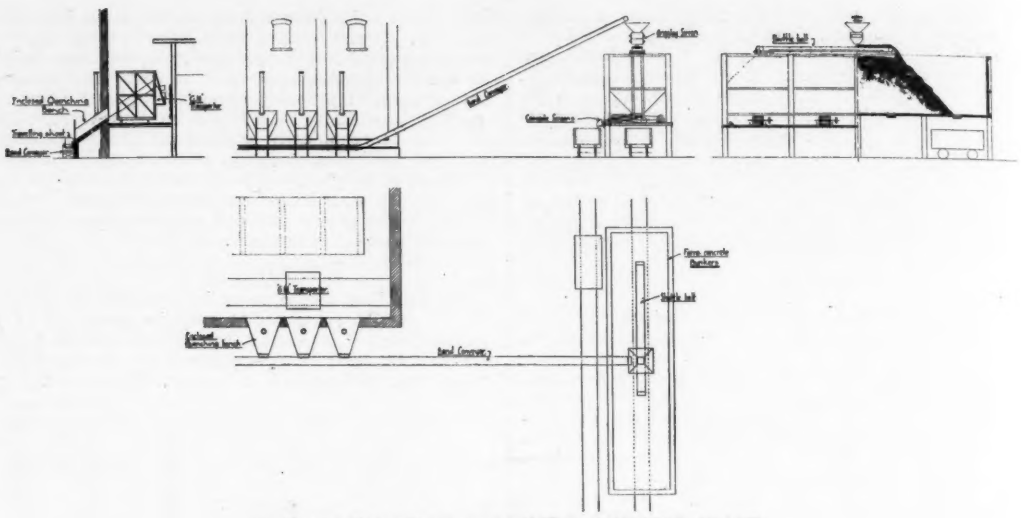


FIG. 5.—LAY-OUT OF SUGGESTED HANDLING PLANT.

separates the breeze; the coke afterwards passing into either of two rotary screens of well-known type, which serve to grade the coke into required sizes. In cases where head-room is of no moment, plain cylinders may be used, but if the screens have to be set at an angle less than about 10° with the horizontal, it is necessary to fit internal helical guides. Rotary screens were formerly built-up of perforated mild-steel plates mounted upon a suitable arrangement of central shaft, "spiders," and angle framework. In modern screens, the perforated plates are replaced by wire meshing of the required size, the latter having proved far cheaper per ton handled.

The "grizzly" screen, and a somewhat similar appliance the "Ross" grizzly, are useful for this operation, particularly for screening coke on to a shuttle belt; but they are usually limited to one grade of screened coke, and their maintenance is rather costly. It is much to be regretted that the first cost of some of these patented screens is out of all proportion to the material and workmanship involved.

For producing one or several grades of screened coke, the machine which gives the best all-round result is probably the "jigger" or shaking screen, particularly when constructed on the cascade principle, and with due regard to upkeep. Such a plant has the advantage of flexibility, and also requires very little head-room. It thus offers the maximum hopper capacity for a given total height. It is essential, however, that the fingers of the screen, and the trough in which they are fixed, should be easily renewable and protected where possible by lining plates, and that all moving parts, such as bearings, suspension hinges, &c., should be placed outside the trough—*i.e.*, out of contact with the coke. A suitable section is shown in fig. 3.

Final Screening.

Screening at the outlet of the hoppers is sometimes regarded as a refinement, if an effective preliminary screening is carried out. There can be no doubt, however, that it is advisable, and the function of such final screening is primarily to eliminate any breeze or dust which may be formed during the passage of the coke through the hoppers. In many cases, notably when North Midland coal is carbonized in vertical retorts, an inclined bar screen (fig. 4) or stationary cascade is found to be adequate. Very little head-room is usually available below the hoppers, however, and in that case a mechanical screen, such as the cascade jigger, or the "Ross" grizzly, may be utilized. In exceptional cases it may be necessary to carry out the final screening on the horizontal, or even on an upward incline. The "Whitehall" screen, which is a drag-bar conveyor passing over a bar screen, is useful for this purpose.

Conclusions.

The writer has endeavoured in the foregoing to review the best available means of transporting, quenching, and grading coke for sale. Bearing in mind the desired result—namely, the production of a fuel as dry and as free from ash as possible, making at the same time the minimum proportion of breeze and dust and having due regard to cost of installation and operation—the best type of coke handling plant may be summarized as follows:

(*a*) Coke from Horizontal Retorts.

The general lay-out of the installation is shown in fig. 5. The charge is pushed out by a ram into the tube of a "G.N." transporter, and thence into the various bays of an enclosed quenching bench. Water is sprayed upon the lower portion of the coke, which is quenched mainly by steam, with which it remains in contact until immediately before the bay is required for the next draw. The coke is then discharged through the bottom doors into hoppers or shoots feeding the first of a set of rubber band conveyors, which elevate it to the receiving hopper of the preliminary screening plant, over ferro-concrete storage bunkers, first passing through a coke cutting machine, if this is absolutely necessary.

The next step—top screening—depends entirely upon the number of grades of fuel called for by the market. If only breeze and one grade of coke are required, the best plant is a grizzly screen, from which the screened coke is fed on to a reversible shuttle belt running the whole length of the bunkers. If two or three grades of coke are called for in addition to breeze, the advantages of "progressive" dumping may be retained by the use of a travelling rotary screen in place of the grizzly. In this case, failing telpher transport, the shuttle belt may be used to feed the screen. Should more than three grades of screened coke be desired, or should either of the foregoing schemes be for any reason inadmissible, it would appear best to instal a cascade jigging screen with the requisite number of toothed sections to give the desired result. In this case, as in the preceding one, the concrete bunkers must be divided-up, to receive the various grades.

We now have finished coke stored in the various compartments awaiting dispatch. All that remains to be done is a final screening as the various grades are shot from the bunker into the wagon or lorry, in order to eliminate the final traces of dust and breeze due to the passage of the material through the bunkers. This is best removed in a small cascade jigger screen acting as a chute, the teeth being so spaced as to retain only the one size of coke which it is required to deliver. Such an arrangement, however, is not always needed if the preliminary screening and dumping have been efficient. In this case, the provision of a cast-iron bar screen in the bottom of the chute is all that is necessary (see fig. 4).

(*b*) Coke from Vertical Retorts.

This is more easily dealt with, as it requires no quenching, and is therefore drier (and usually harder) than quenched coke from horizontal retorts. It is discharged into a skip or, by suitable chutes, into a band conveyor, and is elevated to the receiving hopper of the screening plant. Thence its treatment is on the same lines as above.

The foregoing is considered to be at the present time a perfectly sound and sufficient method of coke handling, as applied to the case of an entirely new installation. It will be noticed that preference has been given throughout to plant which substitutes "sliding" for "dropping" of the coke, and to band conveyors, the chief advantages of which have been noted above. But there is a final and important advantage accruing from the combination of enclosed quenching bench and band conveyor, and that is in labour. Owing to the storage of coke in the bays of the quenching bench, and to the fact that all controls of the conveying plant may be placed at ground level, the above plant applied to (say) 20 beds of 10 retorts could easily be operated by one man per shift, *plus* one man per day for working bottom screens and filling wagons. Thus the daily output of coke and breeze—say, 120 tons—could be quenched, conveyed, screened, and loaded by four men—a labour charge of about 3¼d. per ton.

On general economic grounds, also, the scheme put forward is justified. The plant outlined, of suitable capacity to deal with the coke and breeze from 20 beds of tens—say, 120 tons per diem, or 37,000 tons per average year—would cost slightly over £8000. A similar plant, including "G.N." transporter and enclosed quenching bench, but substituting telpher plant and travelling screen for band conveyor and shuttle belt, would cost about £11,000—excluding coke bunkers in each case. On

this basis the cost of coke handling from retort to wagon would be approximately as given in the following table:

Cost of Coke-Handling in Pence per Ton.

—	Plant Outlined with "G.N." and Band Conveyors.	Similar Plant with "G.N." and Telpher.	De Brouwer of Same Capacity.
Interest and Depreciation .	5·3	7·3	5·1
Maintenance	2·1	2·1	6·5
Running	1·5	1·0	1·0
Labour	10·0	12·7	11·7
Total	18·9	23·1	24·3

The above costs are higher than some previously published for "G.N." handling, but it must be remembered that in this case high standing and maintenance charges are incurred by the addition of enclosed bays to the quenching bench, and bottom screening; and it is certain that the improvement effected in the quality of the finished coke would amply repay such extra cost. Similarly, the De Brouwer figures given in the table for comparison include only for quenching in the conveyor trough, giving an admittedly unsatisfactory product. It is appreciated, of course, that the scheme given is not applicable in its entirety to all existing plants or under all existing conditions. To meet such other conditions as may arise, the various items of the plant would need modification on lines indicated earlier in this paper.

SECTION III.

GAS COKE AS A DOMESTIC FUEL.

First Award, won by "Inconnu."

BY MR. F. H. ARMS, OF BIRMINGHAM.

The disposal of the make of gas coke is a task which confronts every gas manager or engineer. He has to consider not only how to keep his yards clear, but also how to dispose of the coke in the markets which will bring in the largest revenue from this residual, as his selling price of gas depends to a great extent on the disposal of this valuable bye-product.

One of the fields of activity which present the greatest possibility to-day is the domestic or household trade. In catering for this trade, a most important item is supplying the right-sized material, as this is one of the chief reasons for prejudice on the part of the general public against burning coke in the home. The old-fashioned unsized coke was too large to burn freely in the ordinary grate. The coke which has been found to be the most suitable should be screened over 1¼ in. and through a 2-in. square mesh.

Instructions should be given to the public how to attain the best results of burning coke in the domestic grate. The method to obtain a bright fire in a grate having a good draught is to place a small amount of coke on the bottom of the grate, then paper and wood, and on top any cinders left over from the previous day, then a further quantity of coke. It is a good plan to build the fuel towards the front of the grate to a thickness of 6 in. to 9 in., in order that the air may get at the back of the fire. The fire is then readily lighted. In the case of a grate with a poor draught, the fire is best started with a mixture of small pieces of coal.

Another fact which should not be overlooked is feeding the fire at regular intervals, instead of allowing it to burn right down and then adding a large quantity of coke. Always keep the front of the fire to a thickness of about 9 in. An occasional rake-out through the bottom bars always helps to keep a bright fire. An excellent fire can always be kept in the old-fashioned kitchen range by burning small coke. An intense and steady heat for cooking and hot water can be maintained, and in addition there is the reduction in labour by lessening the dirty and objectionable task of cleaning-out the flues of the range.

It should be pointed out to the public that, by burning coke on household fires, chimney sweeping is reduced to a minimum. In addition, the carrying of coke is much lighter work than carrying coal, the latter being very much heavier than coke, bulk for bulk.

The grates now being installed in the municipal houses are very suitable for burning small coke; and every effort should be made to foster the use of coke in these houses.

Comparative Costs.

In persuading the public to adopt gas coke, one must be prepared to prove that it is an economical proposition. The following shows the relative cost of obtaining 100,000 B.Th.U. of heat by the use of gas coke, coal, gas, and electricity:

	s.	d.
Gas coke at 39s. per ton delivered in bags. Calorific value, 13,000 B.Th.U. per lb. (Weight required, 8 lbs.) . . . . . =	0	1·6
Best household coal at 45s. per ton delivered in bags. Calorific value, 13,000 B.Th.U. per lb. (Weight required, 8 lbs.). . . . . =	0	1·8
Gas at 2s. 10d. per 1000 c.ft. Calorific value, 500 B.Th.U. per c.ft. . . . . =	0	6·8
Electricity at 1½d. per unit. Calorific value, 3420 B.Th.U. per unit . . . . . =	3	7·8

In addition to costs, there is the question of actual efficiency of heating by gas coke. The amount of radiant heat given out by a coke fire has been found, by tests, to be 44 p.ct., as compared with only 19 p.ct. in the case of a coal fire.

The following is a record of an actual test showing the heat balance which was reported in the "Times Fuel Number" published a few years ago.

Comparative Efficiency of Coal Fire and Coke Fire in an Open Grate.

		Coal Fire. P.Ct.		Coke Fire. P.Ct.
Heat lost	Heat used in decomposition and volatilization	10	..	1·7
	Heat escaping in flue gases to chimney.	43	..	51·4
	Heat lost in unburnt matter (smoke) .	25·7	..	*Nil*
	Heat in ashes and grate	1·9	..	2·4
Heat used	Radiant heat imparted to room . . .	19	..	44

Coke maintains an even temperature in the room, as compared with the fluctuating heat of raw coal. When coke is used as a fuel, higher calorific intensity is obtained because it has lost its volatile constituents, which, though themselves possessing considerable calorific power, not only absorb heat during the process of decomposition and volatilization, but are easily wasted. Thus, when raw coal is used as fuel, a considerable portion of the heat is necessarily used to distil or decompose it, and the net quantity of heat available for useful purposes is therefore diminished.

Coke only requires the minimum excess of air (30 to 50 p.ct.) to effect its complete combustion, whereas, in ordinary practice, bituminous coal is unavoidably allowed a quantity greatly in excess (100 to 200 p.ct.) of that theoretically necessary. From the industrial user's point of view, this latter advantage is by far the most important, as it tends directly and very materially to improve the efficiency of steam-raising and other heating operations.

The proportion of volatile matter contained in a solid fuel is, in fact, a measure of the difficulty of burning it efficiently with-

out the formation of smoke and consequent waste. Bituminous coal contains as much as 35 p.ct. of volatile matter, including 3 to 5 p.ct. of hydrogen. Gas coke contains only 2 to 3 p.ct. of volatile matter, and only a trace of hydrogen. Compared with even the best qualities of coal, coke is relatively uniform in character and composition. It contains practically only one combustible constituent—fixed carbon—which is by far the most important heating agent in any solid fuel. For the simple reason that it contains few or no volatile constituents that can be wasted, the combustion of coke is a relatively simple process, and therefore less liable to abuse at the hands of inexperienced stokers. In coke firing, the significant features are the intense radiant heat and the relatively high percentage of CO_2 to be found in the flue gases in ordinary circumstances; 14 to 16 p.ct. being recorded over long periods of working. That coke, in common with most fuels, contains sulphur cannot be denied. Coal and fuel oil, for instance, contain as much as 2 to 3 p.ct., or more, of sulphur, which almost invariably is half volatile and half fixed. Carbonized in gas retorts at the usual temperature, the volatile sulphur in coal is almost entirely driven-off, leaving only the fixed sulphur in the coke. Coke contains, therefore, certainly not more sulphur than coal, but, being deprived of its tarry matter, there is in coke nothing to disguise the unpleasant odour of heated sulphur. Sulphur is, therefore, more in evidence than smoke when coke is burnt under improper conditions which allow the escape of combustion products in directions other than the flues and chimney.

Volatile sulphur is primarily the destructive element in coal so far as the corrosion of boiler plates is concerned. That coke is no more destructive than coal is proved by the comparatively long life of coke-fired steam boilers. Boilers of forty years' service working at their original, even at increased pressures, are common at gas-works. As regards water-tube boilers, which probably are in this respect the most sensitive and easily damaged, it was given in evidence before the Coal Smoke Abatement Committee that a Babcock & Wilcox boiler, hand fired on coke fuel exclusively, had not had a single tube renewed in twenty years' service, whereas using Yorkshire coal slack on similar boilers, it has been necessary to renew damaged tubes in a week. For similar reasons, coke is less destructive of the grates and firebars of steam boilers.

Coke is now being used largely in place of coal for large steam boilers, not for any sentimental reason, nor even primarily with a view to prevent smoke, but simply on its merits as the most economical fuel. Experience has shown that the relative low efficiency of the average coal-fired steam plant is occasioned very largely by the admission to the furnace of large quantities of air in excess of that necessary. This is often done to dilute or diminish the density of smoke in order to comply with police regulations. In the aggregate this practice must waste a large quantity of coal and, at least during the hours of daylight, retard output.

These conditions have, however, paved the way for the introduction of coke. Its introduction on its merits after exhaustive tests has in every case proved its efficiency simultaneously with improved methods of firing, and has tended to fix in the minds of most users the relative value to them of coal as compared with coke, and thereby to establish a reliable market for the latter.

Air in excess of that theoretically necessary must of course be used, or a combustible gas called carbon monoxide (CO) will be produced, and pass away unburnt with the waste products of combustion, entailing a direct loss in the proportion in which it exists. A high percentage of CO_2 in boiler flue gases usually suggests the presence of CO, and consequent waste; but however true this may be in the case of coal-fired boilers, careful tests have failed to reveal more than a trace of carbon monoxide in the flue gases of boilers fired, on rational lines, exclusively with coke.

Sizing of Coke.

The sizing or grading of coke is a most important factor bearing on the efficiency of coke as a fuel for various purposes. The material should be well screened and separated into the following sizes:

(1) Large coke over a screen with a 2-in. mesh.
(2) Small coke over 1¼ in. and through a 2-in. mesh.
(3) Inch breeze over ¾ in. and through 1¼-in. mesh.
(4) Bean breeze over ⅞ in. and through ¾-in. mesh.
(5) Rough dust—material through the ⅛-in. mesh.
N.B.—All the screens to be of square mesh.

The large coke will be found to be the size required for all branches of the metal trade where a fierce heat is required for melting purposes. This sized coke is required also for many branches of trade, such as: Glass blowers, japanners, enamellers, brick makers, maltsters and brewers, bakers' ovens, tar distillers, laundries, oil refiners, chocolate makers, steam lorries, milk sterilizers, gas stove makers, asphalters, cement works, oxygen gas makers, bacon drying, spring and axle trade, metal bedstead trade, galvanized and corrugated sheet-iron trade, tube works, wrought hollow ware, iron plate and tin plate trade, varnish and paint makers, pen makers, boiler makers, open fires for watchmen's huts, and steam rollers.

There is also the large type of heating apparatus which requires big coke. This types of apparatus is installed in public buildings and large blocks of offices, public baths, hospitals, schools, churches, chapels, institutions, theatres, music halls, picture houses, works, warehouses, libraries, botanical gardens; and nurseries having large glass houses heated with steam pipes, and the larger type of central heating.

In addition to the foregoing, there is the coke-fired steam wagon, such as the "Sentinel," "Atkinson," and "National." With suitable firebars coke is very efficient for most types of steam wagons. A standard 6-ton "Sentinel" averages 15 miles per cwt. of coke used, carrying a useful load of 6 tons. A Clarkson 3-ton steam wagon on test, having a gross running weight of 6 tons 11 cwt., showed the average coke consumption to be 3·84 lbs. per mile over 219 miles at 12 m.p.h. These actual workings show that the use of coke on these vehicles is an economical proposition. Also, by using coke on these steam lorries, we have no trailing clouds of smoke and soot in the streets.

Large coke can also be used extensively as fuel on river and canal steamers, dredgers, hoppers, ferry boats, steam lighters, brigs, tenders, and for the donkey boilers of large steamers lying in port. The use of coke on steamers has been found to overcome the smoke nuisance on rivers where residential property is situated in close proximity.

In the case of hand-fired boilers with a satisfactory natural draught, an average hourly rate of coke consumption of 16 lbs. per sq. ft. of grate area is often maintained; and where forced draught is available, this rate is often exceeded. It is therefore clear that, with coke exclusively as fuel, the output of hand-fired steam boilers can be maintained at the normal rated capacity.

Small coke is the domestic or household size. It burns well in the ordinary grate having a good draught, as already mentioned. For the old-fashioned range and hot water supply boilers it is an ideal fuel. This size of material is the fuel required by sweet boilers, cooked meat trade, tailors, fish frying, and grills in hotels. Some of the tube and spring makers prefer small coke to inch breeze on their hearths. All types of smaller heating apparatus consume small coke satisfactorily.

Inch breeze is the size required by the smithies, welders, and the tube trade generally, for use on hearths. It is very suitable for burning in anthracite stoves. A stove well filled with inch breeze will last eight or nine hours, and shows a considerable saving compared with anthracite coal. Some householders burn inch breeze mixed with small coal in open grates, and an excellent fire is thus obtained. This size of material makes a good fuel for use on greenhouse fires; well backed-up, the fire will last throughout the night.

Bean breeze is in general use for smiths' hearths and all smaller types of forgings. Building contractors employ this material in the making of concrete floors.

Rough coke dust mixed with slack is now being consumed on chain-grate boilers in large quantities by electric supply departments, and shows a considerable economy in fuel costs. There are several types of furnaces—*e.g.*, the "Crossthwaite" and the "Wilton"—which are specially constructed to consume coke dust. During the last few years another outlet has been created for this material by the use of breeze slabs in the building of houses. To make the slabs, rough dust is mixed with portland cement. Landscape gardeners often prefer this material for laying under lawns, for drainage.

Desirable Characteristics of Coke.

In the production of a coke which will suit the general users of the fuel, there are several points of efficiency which the gas undertaking should endeavour to attain. The coke offered for sale should be well screened into the various sizes, and should be free from dust. It is a good plan to have a final mesh at the outlet of the hoppers of the various sized materials, in order to screen-out any dust that may collect in the hoppers. In this way the fuel is again screened as it actually falls into the railway wagon or customer's cart. In spite of regular cleaning, dust is always collecting on the side of the hoppers, and unless there is a further mesh to pass over, it finds its way among the materials supplied to the customer.

Another difficulty which the salesman has to contend with is the moisture in coke. This is generally found in the coke carbonized in horizontal retorts. By the adoption of the vertical retorts this is overcome, as the retorts, being tapered internally, allow the coke to swell during the process of carbonization, thus producing coke which usually is comparatively light. Moreover, this system possesses the advantage of producing practically cold coke, thus eliminating the necessity of quenching with water. Coke carbonized and steamed in the continuous vertical retorts is greatly preferred to-day by many large users, as a light-grey dry coke is thus produced, which burns easily. This coke is also very suitable for burning under bakers' ovens, as often these are in a confined space, and it does not need the draught required by the heavier horizontal coke. Small coke from vertical retorts is the most suitable kind for household use, for, owing to its light and dry nature, it burns freely in open grates.

The difficulty experienced by householders in starting a coke fire in domestic grates has been found in many cases due to the excessive amount of moisture in the coke. When a gas under-

taking is compelled to export its surplus make of coke, it will find that vertical coke is preferred by the foreign buyers, owing to its light nature, as abroad they buy by weight and often sell by measure.

An objection many housewives to-day have against burning gas coke in domestic grates is the high ash content in many kinds of coke. This makes a dirty and dusty hearth. The percentage of ash varies from 5 to 13 p.ct.; and every precaution should be taken to purchase a coal producing a low ash content in the coke, especially where an undertaking wishes to create a household trade.

A typical proximate analysis of ordinary unwashed gas coal of average quality would be as follows:

	P.Ct.
Moisture	1·35
Ash	8·21
Volatile hydrocarbons	27·19
Fixed carbon	61·59
Sulphur	1 66

It has been pointed out by some colliery owners that, if coal was purchased on a strictly limited ash-content basis, they would be forced to instal washing plant in order to comply with the users' demands. Experience shows that the improvement in value of the coal so treated justifies the cost of washing. The average ash content of good gas coal should be of the order of 6 p.ct.; and this proportion should be the limit that should be accepted. The ash content of coke resulting from the carbonization of such coal at ordinary high temperature would be about 8 to 9 p.ct.

The following is a proximate analysis of good average quality gas coke on the dry basis:

	P.Ct.
Carbon	88·0
Hydrogen	0·5
Oxygen	Trace
Nitrogen	2·0
Sulphur	1·5
Ash	8·0

Another point to bear in mind when purchasing gas coal is to buy coal containing a minimum amount of bat. This is most important when the breeze trade is cultivated. In the welding and forge trade it is necessary to supply breeze free from bat, as this objectionable substance is present to a greater extent in the smaller-sized materials than it is in the large coke. If the bat is left in the breeze, when the fierce blast of the smith's hearth is played on the fuel the bat will either fly, which is dangerous to the man working, or run on to the metal which the smith is working upon. To overcome this difficulty the breeze should be purified or washed to remove all foreign matter. The "Coulson" washer is excellent for this purpose. The residue or sinkers can be disposed of as a cheap boiler fuel or for use on greenhouse fires.

Heating of Houses.

In every household of the average type, a continuous supply of hot water is required for general domestic purposes, baths, and sometimes for heating radiators in the hall or passages. The old-fashioned range is wasteful, and during summer months the use of the kitchener means discomfort, owing to the heat thrown out into the kitchen. The following is a description of a simple, efficient, and extremely economical means of obtaining all the hot water required for all needs.

The boiler can be installed in the kitchen, in the recess previously occupied by the old-fashioned range or kitchener. The recess in which the boiler stands is lined with tiles, which are cleaner, and need no blacklead—only a damp rag is required to clean these tiles. The boiler, of which there is a wide range to choose from—viz., the "Hydresse," "Ideal," "Cottage," "Sentry," "Glow-Worm," "Domestikatum," "Cultivatum," "Koke"—is connected to the previously existing hot water circulating pipes running over the house, which supply a hot water tap in the scullery, a radiator in the hall, and a lavatory basin and bath in the bathroom, while the heat which escapes from the hot water tank at the top of the house is utilized for airing clothes—the large cupboard in which they are placed being around the tank.

Those who have used the old-fashioned coal-fired kitchener know how much time is spent each week in cleaning. It was necessary to brush-up every day, and to blacklead and clean out the flues at least once a week. The modern coke boiler is cleaned by blacklead very seldom, and the cleaning of flues is done away with by burning this smokeless fuel. If the fire is allowed to go out at night, within 20 minutes of re-lighting the water in the pipes is quite warm, and within one hour a hot bath is obtainable. No clinkers form in the coke boilers, as a good draught is obtainable by opening the bottom door of the boiler, to obtain quick combustion. The boiler is not built right back in the recess, but protrudes slightly into the room, so that heat escaping from the boiler warms the kitchen in the winter. On the other hand, in the summer, with a slow fire, the heat from the boiler is hardly noticed. These modern coke boilers have a door which can be opened during the cold months to show a cheerful fire. Means are also provided for heating flat irons, and the top of the boiler can be utilized for warming plates, &c. Also, saucepans can be placed on the top of the boiler.

As regards consumption of fuel, on the coldest days, 30 to 40 lbs. of coke meets all the demands of the household. Of course, for ordinary cooking, one would use a gas cooker. No kitchener could do this work so satisfactorily under all conditions as do the coke boiler and gas cooker together.

There is an excellent type of domestic open-fire boiler on the market to-day called the "Thermostove," made by Hartley & Sugden, Ltd., of Halifax. This has an oven over the stove, in which the cooking can be done. In the oven, gas burners can be fitted, together with side brackets, each bracket having two gas boiling rings. These can be fitted at a small additional cost. This is especially useful in the summer, and obviates having a fire in the boiler for long periods.

The boiler capacity of this stove will easily supply 36 gallons of water every hour at 100° Fahr. It provides three consecutive hot baths if required. The size of the oven is 16 in. wide by 14 in. high by 15 in. deep, and it is fitted with sliding doors. This type of boiler will supply hot water for towel rails and radiators; and by burning coke it shows a total efficiency of almost 75 p.ct. All the heat from the fire passes into flues surrounding the oven, which is placed above. This position eliminates the necessity for bending-down when attending to the cooking. Towel rails are fixed on the outer sides of the oven.

There is an impression that a combined cooker and boiler can be installed for unlimited requirements, but there is a point beyond which the combination not only becomes inefficient, but almost impracticable. If a service is required for heating more than four radiators, in addition to hot water requirements, a larger boiler is required; and the makers of the above boiler make two boilers in one, called the "Duo-Boiler." This is an independent boiler divided into two entirely separate units—the bottom unit for radiator heating, and the top for hot water service to taps. The boiler has two grates, and in the summer, when no radiators are required, the bottom unit is placed out of action by the use of the top firegrate attached to the domestic supply unit of the boiler.

A further method of heating houses by burning coke is by the open fireplaces, but some grates will burn coke only with a certain amount of trouble, if they happen to have a poor draught. The public can now obtain a grate specially built for burning coke; this is the "N.C." open coke-burning fire grate made by R. & A. Main, Ltd., of Edmonton.

The principle on which this grate is constructed is a series of deep vertical channels in a one-piece firebrick back and sides. The channels, which extend from the hearth level to a point above the normal level of the fuel in the grate, function as miniature chimneys, inducing currents of air inwards through the fuel bed from the front towards the back and thence upwards through the channels. The induced, or convection, currents have in practice proved to be sufficient to maintain gas coke in brilliant and satisfactory combustion. When it is desired to retard or control combustion, to suit varying atmospheric conditions, the ventilator in the ashpit cover or fret is adjusted, or the fret is opened. This admits cold air to the lower ends of the channels which communicate with the ashpit and the under-side of the fire grating. The channels being thus chilled, the upward draught is diminished and is no longer concentrated on the fuel, but merely pulls-in more or less cold air through the ashpit. Combustion is therefore slowed-down or controlled as required. In an ordinary grate this operation is, of course, just the reverse; the fret being opened to promote quicker combustion. In the event of a hot water supply being required for use in connection with the "N.C." grate, a boiler, having the front heating surface ribbed or corrugated to correspond with the channelling of the back brick may be provided.

Another feature of this grate is an adaptable damper in the canopy. By this means the air circulation through the room can be accurately regulated not to exceed that necessary for efficient ventilation, whatever the height of, or draught in, the chimney. This is an important feature bearing on economical use of fuel for domestic heating. The grate is supplied in any style or size for cottage, living rooms, halls, larger dining or drawing rooms, and when used in conjunction with a gas cooker and gas fires in bedrooms, renders the house smokeless and independent of crude coal as fuel.

In addition to the foregoing methods of heating houses by smokeless fuel, there is the central heating system, which is attained by a system of hot water pipes throughout the houses connected to a radiator in each room, on landings, and in the hall. The water is heated by a boiler in the basement of the house or an outhouse adjacent to the house. The ideal fuel for these boilers is undoubtedly gas coke sized according to the type of boiler.

There is another method of central heating, by hot air instead of hot water, brought out by the British Pipeless Central Heating, Ltd., of London. This principle of heating is based on the physical law that cold air, being heavier, will descend, while the warm air, being lighter, will ascend. This system has a furnace in the basement, and over the furnace is a grating in the front hall. The hot air is delivered through the grating, ascends the stairs, and permeates throughout the house. To assist the movement of the air, the furnace is provided with two sets of casings, an inner one which is the compartment for the warm air, and an outer one containing cold air drawn from

the various rooms. When the warm air rises through the inner casing, it proves that an equal amount of cooler air has passed down through the outer casing. The furnace, which is within the inner casing, is so designed that the maximum heating surface is exposed in the casing. At the same time, the furnace is sealed so that no gases of combustion can at any time come in contact with the air in the casing. Such gases pass away by a separate flue. When the furnace is lighted, the air in the inner casing is heated, expands, and rises into all the higher parts of the house. At the same time the cold air in the house descends through the casing to the lowest part of the furnace, when it passes into the inner casing, and is heated in its turn, and rises. To warm the house rapidly with this system, the doors inside the house should be left open. This system is suitable for old types of houses having a basement.

The great advantage of central heating is that the temperature throughout the house is the same; and this system is being adopted by a great number of the larger type of houses to-day, thus creating a constant trade for gas coke.

Adoption of Gas Coke as a Fuel from National, Regional, and Local Points of View.

Coal is without a doubt the lifeblood of this country, and it is upon the widespread and immensely valuable deposits of coal, affording the provision of heat and power, that the wealth of our nation has been built. We, as a nation, have in the past made the least, instead of the most, of this great asset. The time has now arrived when we must either mend our ways in this respect or become bankrupt and rank as a back number among more progressive nations. The remedy lies in the scientific utilization of raw coal and the adoption of smokeless fuel. The quantity of coal consumed per annum in the United Kingdom is about 175,000,000 tons. It is estimated that one-third of the coal consumed in the United Kingdom is wasted, owing to want of sensible and scientific carbonization. The present consumption of 40,000,000 tons of coal per annum in the United Kingdom for domestic purposes implies a loss of 400,000,000 gallons of oil. In the British Isles, the annual production of coal smoke by the burning of raw coal is equivalent to 3,000,000 tons of sulphuric acid, most of which is showered down in rain. In the City of London more than 650 tons of soot falls to the square mile per annum, and in the Administrative County of London 76,050 tons per annum. This includes 6000 tons of ammonia, 8000 tons of sulphate, and 3000 tons of chlorine, combined as chlorides. The money lost due to smoke and fog in London resulting from the use of raw coal is estimated at over £3,000,000 per annum. An equivalent waste occurs in our provincial cities and towns.

At last the evil effects of coal smoke upon the human body are being recognized by the medical profession. The sun is being accepted as the world's antiseptic, and without a doubt a smokeless atmosphere would do more to rid us of our diseases than would any other means of prevention. In this connection the use of soft coal as a fuel in New York was prohibited in 1905 for the specific purpose of combating pulmonary tuberculosis. During the following fourteen years, 1905 to 1919, the death rate in that city from this particular disease was reduced by 50 p.ct. without any new factor being introduced for the suppression of tuberculosis.

In an address on this subject to the members of the London Society, Dr. Saleeby said: "It is infamous that, possessing such a treasure as Westminster Abbey, we should eat it away as we do by the sulphuric acid derived from the stupid destruction of one the most valuable ingredients of our coal. But my concern is with public health. The evidence for sunlight derived from my North America visits, in Canada no less than in the United States, led me to define certain of the commonest and most deadly diseases of our own cities as 'diseases of darkness.' Of these the worst is tuberculosis. It was evident to all, skilled or unskilled, in observing tuberculosis, that the disease can be cured, even in extreme and desperate cases, by exposure to sunlight. At Alton and Hayling Island, Hampshire, I found Sir Henry Gauvain curing tuberculosis with sunlight just as Dr. Rollier does at Leysin, in Switzerland. The lesson it teaches is that the diseases of darkness would go the way of leprosy and the plague—into the limbo of medical history—if we applied to the tasks of creation and prevention the same primal and celestial agent which in such hospitals fulfils the old words, 'And they that dwell in the valley of the shadow of death, upon them hath the light shined.' We must have more light. Not for tuberculosis only, nor anæmia only, but for a host of disorders of growth and defects of physique. The restoration of sunlight to our malurbanized millions, now blackened, bleached, and blighted in smoke and slums, is the next great task of hygiene in our country."

The following extracts are from Lord Newton's Report to the Ministry of Health and Committee on Smoke and Noxious Vapours Abatement:

"It is useless to expect in the present state of our knowledge that any law can be practically applied to the fireplaces of common houses, which, in a large town like London, contribute very materially to the pollution of the atmosphere."

"Two members of the Committee have visited the principal industrial towns of the Rhine Province and Westphalia, with a view to ascertain comparative conditions in regard to air pollution obtaining in Germany and in this country. . . . The report shows clearly that the comparative cleanness of the atmosphere in German towns is due not so much to the action of the Government as to the intelligent co-operation of all parties in the interest both of the most economical and effective use of fuel and of the general amenity of life. Small houses are heated by stoves which are generally fired with coke, and are therefore smokeless. The evidence shows clearly that a large percentage of the smoke in the atmosphere of towns comes from chimneys of dwelling houses. The burning of raw coal is a dirty, wasteful, and unscientific practice; and on grounds of economy as well as public health it should be restricted as much as possible."

The prohibition in this country of the use of soft coal is impracticable at present as the country's resources in smokeless fuel are inadequate, but there is no apparent limitation to the extent to which the supply of smokeless fuels could be augmented by the carbonization of soft coal.

Coke-Selling Organization.

In the disposal of the make of gas coke, it is necessary for an undertaking to have a selling organization. Too often the selling is in the hands of the gas engineer, who has quite enough to do in producing gas and paying attention to the quality of the coke made for the various demands of the locality. An engineer who has to sell his make of coke has not the time to devote to good and careful distribution, and often, when he finds the local demand does not absorb his make, instead of having a sales department to develop the trade, disposes of his surplus in another undertaking's area by underselling that undertaking's local price.

Those who adopt this practice should bear in mind the old axiom "A boy can undersell, but it takes a man to maintain the price." Markets for the disposal of coke cannot be produced by a wave of the magician's wand. They exist in most undertakings' areas, but they need development. This development can only be brought about by concentrated effort and work by a trained and enthusiastic selling staff. We have our gas salesmen and canvassers; but how many gas undertakings have coke salesmen and canvassers? To create business, it is necessary to have the "outside man." Five minutes' good and convincing talk will do more good than twenty letters sent to a prospective customer. From the writer's own experience, it is absolutely necessary to make a call on a manufacturer if you wish to obtain his order in face of competition from coal. The coke salesman should be familiar with all kinds of furnaces and heating apparatus, and he can then recommend, after seeing the apparatus, the material most suitable for the consumer's use.

Many manufacturers in my own town are using coke to-day only as a result of a personal visit and advice given. In order to have the whole of the area covered, it is a good thing to cultivate the merchants' trade. The merchants should be told the chief points to bear in mind in selling coke, and their selling price should be fixed for them. This should agree with the gas undertaking's retail delivered price, thereby avoiding needless underselling, and leaving a fair margin of profit for the merchant. Advantages in price should be given to the large consumers who can take their supplies by railway wagon to local stations. Some undertakings I know adopt a sliding-scale of prices according to tonnage taken; but this system, if applied to merchants, is apt to lead to the practice of underselling, for if one buys cheaper than another, the merchants taking large quantities can undersell the smaller merchants and still work on some margin of profit.

Every effort should be made to cultivate a cart or motor delivery trade, as this is a very paying proposition, and also the most regular. With care, the haulage in itself can show a profit. Delivery should be made loose, tipped on to consumer's premises, also delivery in bags carried to any part of the customer's premises. An extra charge of 2s. per ton will amply repay an undertaking for the latter manner of delivery. Another mode of selling is for customers who have their own vehicles to send to the gas-works for their supplies. The material can be supplied loose, or, if the customer requires it loaded into his own bags, an extra charge of 1s. per ton will cover all costs incurred. If the gas-works are situated on a canal, the opportunity should be taken to sell by boatload. In this case a good plan is to sell on canal gauging, as an independent weight often removes the chance of disputed weighings.

A method of cultivating a household trade among the poor of our large cities is to supply them with ½ cwt. and 1 cwt. of coke for cash, fetched from the gas-works. On cold days in the winter, the writer has seen outside the gas-works queues of several hundred people, with their barrows or small trucks. Arrangements should be made with merchants to supply in similar quantities to the poor around the wharves some distance from the gas-works. Small dealers and coalyards should be induced to cater for this class of trade. During the summer months, stocks at the gas-works may be kept down by inducing the largest consumers to put a quantity of coke to stock on their premises as a safeguard against a possible shortage during the winter, as was the case two winters ago.

As already mentioned, the household or domestic trade is one

which needs developing in most towns. Thousands of householders are not using coke to-day simply because the matter has not been brought before their notice. An intensive and concentrated form of advertising and publicity campaign is necessary to convince the public that burning coke in the home is economical and necessary from a health point of view. Advertising in all forms should be adopted. Show screens on the theatres, music halls, and picture houses, together with programme advertisements. In the public notice columns of the Press, small adverts should constantly appear.

When sending out the gas accounts, have a coke advertisement shown on the account, or enclose a letter or pamphlet showing the advantages of using coke against coal. Make a special point of delivering single bags for trial, and follow-up each trial order with a personal call on the part of the coke canvasser, to see if the burning of the fuel was a success. The canvasser should give advice how to obtain the best results; and a repeat order for larger quantities will be obtained. Careful note should be taken of any customer who ceases to use coke, and a personal call should be made to inquire the reason. Often a different-sized material will cause the order to be renewed. A few trained canvassers will soon increase, and keep, a good household trade. The personal element is necessary to keep this class of trade, the same as in ordinary commerce to-day. Let a traveller omit calling on a customer, and his firm soon lose the order. The same applies to the coke trade.

Gas undertakings should bear in mind that our largest business houses to-day are built up on intensive advertising and selling organization; and the same principles must be applied to the selling of the make of coke. All correspondence should have adhesive seals referring to smoke abatement. Take every opportunity of placing before the public the advantages of using coke. In every gas showroom a coke fire should be shown burning in an open grate, and also various types of hot water apparatus. This plan could have been adopted at the British Empire Exhibition at Wembley last year. In fact, a stand devoted to coke showing various sizes being used for different purposes would have been a useful addition to the Gas Exhibit. This omission has been rectified to some extent this year. Gas undertakings should show coke and its uses at all trades exhibitions.

If an undertaking is compelled to export its surplus coke, never deal direct with foreign countries—always sell through a first-class firm of shippers. Their small commission is amply compensated by the security of getting payment for coke so disposed of.

In conclusion, after sales have been effected, remember "service" is the means of the order being retained. Let your customer see you are interested in his requirements, and give the fullest attention to complaints of all kinds. Have motor transport in case of urgent calls, and so show to your customer that you are at his service.

SECTION III.—GAS COKE AS A DOMESTIC FUEL.—(*Continued.*)

Second Award, won by "Thermopolitan."

BY MR. E. W. L. NICOL, Assoc.I.C.E., A.M.I.E.E., M.I.Mar.E., OF LONDON.

The Sale, Distribution, and Use of Coke.

To supplement gas as a domestic fuel for continuous heating and constant hot water supply, and thereby to realize and contribute the maximum revenue towards the reduction of the price of gas, should be the chief function of coke. That coke is not only complementary and supplementary to gas as a domestic fuel, but also indispensable, in a scheme of modern house-heating and cooking, is a fact that cannot be ignored. Gas alone for continuous heating and hot water supply is in many cases too expensive; but gas supplemented by coke is without doubt both economical and effective. Conditions obtaining in the districts of any two gas undertakings may not be approximately similar; but, having regard to the economic dependence of gas upon revenue derived from coke, the ultimate aim in all cases should be to produce, prepare, and utilize coke so that it fulfils its most important and natural function in the efficient conduct of a gas undertaking—namely, to facilitate and promote the use of gas as fuel for domestic purposes.

A natural outcome of the displacement of the kitchen range by the gas cooker has been the evolution of the independent coke-fired hot water boiler. By means of radiators, connected to a coke boiler, the atmosphere of a house may readily and continuously be tempered so that the gas fire is rendered adequate and economical, even in the coldest weather. Coke does not therefore compete with gas, but rather facilitates and promotes its use for purposes which otherwise, on the score of cost, would, and do, render its use prohibitive.

Of the 40 million tons of coal used annually for domestic purposes, probably one-fourth is used more or less wastefully in heating water for uses other than cooking. The total yearly output of gas coke, about 8 million tons, might therefore be absorbed for this purpose alone. The possible outlet for coke, by means of the coke boiler, is in fact unlimited; and this means of promoting the use of coke should prove to be the means of promoting also the best interest of gas, in more ways than one.

Domestic and Industrial Uses.

In the order of their ultimate importance, the domestic and industrial uses of coke might be listed as follows:

Domestic.— Continuous hot water supply.
Central heating.
Open fires.

Industrial.—Bakeries.
Central heating (including glass-house heating).
Steam-raising (hand-fired).
Steam-raising (mechanical stoking).

For most industrial, and quasi-industrial, purposes, coke and coal are interchangeable fuels. In these markets coke is therefore forced into competition with relatively cheap classes of fuel, at prices considerably less than those realized in the domestic market, where competition is more restricted; and having regard to the immense quantities of coal used annually for factories and for domestic purposes—*i.e.*, about 90 million tons and 40 million tons respectively—and the relatively small quantity of coke produced, the need for coke competing in the industrial fuel market should, with careful preparation, tend entirely to disappear. Even if the industrial market is entirely ignored, the ratio of coal used to coke available for sale in any district is probably more than 4 to 1; so that the domestic market alone should easily absorb the whole coke output of the gas industry. But while the domestic market for coke should in all cases be regarded as the ultimate objective, the cultivation of the industrial, and quasi industrial, markets must meanwhile receive the care and competent attention which their importance clearly demands.

Competing Fuels.

Those concerned technically and commercially in the conduct of the gas industry realize, no doubt, the nature and potentialities of the propaganda and competition which must be met and overcome in whichever direction it is proposed to displace other fuels with coke. That such propaganda and competition can often be turned to good account in the interest of coke is perhaps not quite so obvious. Unscrupulous dealers who are pleased to describe themselves as coal and coke merchants, for instance, frequently do not hesitate loudly to decry coke when it is in their interest—as it often is—to supply coal rather than coke. Such transparent self-interest need only be exposed in order to make it defeat its own end.

Anthracite.

The powerful interests and selling ability behind the movement to popularize anthracite is reflected in the inordinately high prices demanded and obtained for this somewhat overrated fuel. The fact that users, having for various reasons been forced to experiment with other fuels, have discovered in suitably-graded coke a relatively cheap fuel, which in every respect is a satisfactory substitute for anthracite, is not generally known. The present output of South Wales anthracite is 5 million tons per annum, of which probably 75 p.ct. is exported.

Furnace Coke.

In furnace coke, the product of the coke-oven plants, we have a potential competitor in both the home and export markets which commands the greatest respect. In this country, and to a far greater extent in America, a definite line of demarcation between the gas and the bye-product coke industries is increasingly difficult to draw. Adaptation of the bye-product oven to the needs of town gas manufacture has brought into

existence a number of installations of bye-product ovens as a part of existing gas-works; and independent coke-oven plants now supply gas, in increasing quantities, under contract, to public utility undertakings.

In the practical operation of a coke-oven plant, the fact that, instead of being wasted as heretofore, surplus gas may be sold for distribution through a gas supply undertaking, tends unfairly to enable furnace coke to compete with gas coke, in both the home and export markets; and the extent to which furnace coke can permanently compete in these markets will depend not only upon the revival of the iron and steel industries and a legitimate outlet for furnace work, but also upon the revenue derived from the sale of gas to the producers of gas coke.

Low-Temperature Coke.

The low-temperature process may be regarded as a possible subsidiary development of the colliery and coke-oven interests. Owing to economic handicaps, which need not be discussed here, low-temperature coke need scarcely be considered as a serious competitor. The public interest in all low-temperature processes, designed to produce a smokeless solid fuel, presupposes the unsuitability of gas coke as a domestic fuel. That good gas coke can, and does, do all that is claimed for low-temperature coke need only be demonstrated in order to secure advantage from the public interest aroused by the wide publicity which discussions on the subject have received in the Press.

Lignite.

Lignite might not be regarded even remotely as a serious competitor of gas coke; but the fact is that, indirectly, lignite is already competing in our export markets. Coal and coke released for export as a result of the increased use of native lignite as fuel for power purposes in Germany may indeed be regarded as competitors of great potential in this direction.

Electricity.

Electricity may be considered not as a competitor, but as a potential ally of coke. The use of coke as a means to economy in the operation of electric generating stations is a subject that will be dealt with in due course. The failure of electricity economically to provide for continuous heating, or even a partial supply of hot water, in the scheme of the "all-electric" house, provides a valuable opportunity for the introduction of the domestic coke boiler; and on the principle that half-a-loaf is better than no bread, no effort should be spared to prove to electrical competitors that, in fact, the coke boiler paves the way to the success of their domestic heating and lighting proposals. Constant and ample hot water at the minimum cost is in this connection a matter of vital importance; and the coke boiler may indeed prove to be the key to the problem of improving the load factor on the proposed super-industrial power stations by facilitating domestic uses for electricity.

£ s. d. of Domestic Fuels.

Finally, the relative commercial values of the domestic market for solid and other fuels should be grasped in their true perspective. In one case, which may reasonably be assumed to be typical of quite a large number, coke only is used for the open fire, hot water boiler, and radiator; gas only is used for occasional heating, ironing, for heating a washing machine, and for cooking; and electricity for lighting and for driving a washing machine. The annual charges at present prices, according to accounts, are, approximately, £16 for coke; £8 for gas; £6 for electricity. These figures tend to prove, if such proof were necessary, the relative importance in numerous cases, of the domestic solid fuel and gaseous fuel requirements from the viewpoint of revenue.

Local Conditions.

As already stated, conditions obtaining in different districts will vary between wide limits. In a colliery district, for instance, coke would be required to compete, in the industrial field, with coal of the cheapest descriptions. Domestic coal, however, is in colliery districts often notoriously dear, and atmospheric smoke pollution usually is serious. The carbonizing plant employed, and the coal supply available at the gas-works, will also have a profound influence upon the characteristics of the coke produced, and its suitability for various purposes and processes carried on locally.

Starting *de novo*, with a view to promoting a good local demand for coke, one would therefore consider, on the one hand, the type of carbonizing plant employed, whether vertical or horizontal; the cutting, screening and loading plant, and distribution facilities; the coal used; the characteristics of the coke; and the extent to which these factors are advantageously and economically variable. On the other hand, a survey of the district, the industries carried on, the competing fuels, and the culinary habits, appliances and customs of the inhabitants would reveal the potentialities of the district to absorb coke for industrial and domestic purposes.

In a purely residential district, the outlet for coke would be limited to domestic uses—*i.e.*, hot water, cooking, heating and open fires, and quasi-domestic uses, such as public baths, bakeries, laundries, hotels, clubs, churches, water-works, glass-houses and nurseries, and hospitals. In an industrial district there should be, in addition to these possible outlets, the possibility of remunerative sales in some of the industries carried on, as in furnace work and steam raising, especially if regulations in respect of smoke emission are enforced.

While keeping in view the ultimate ideal of an adequate domestic market for coke, the vagaries of climate, and trade depression due to seasonal requirements for coke, relative to those of gas, must in many cases necessitate the cultivation of a market for steam-raising and other similar purposes, if local prices are to be stabilized and if large stocks, and consequent dumping, are to be avoided.

Domestic Uses.

Domestic uses for coke, in their present order of importance and general applicability, include the following: The open fire; the closed stove; the kitchen range; the independent hot water boiler; and central heating.

In Great Britain, the climate demands in most districts some form of continuous heating throughout the day during six or more months of the year. In the ordinary household, the open coal fire is most favoured for this purpose. In many cases this fire serves also for cooking and water-heating; in other cases, at least one additional open coal fire, frequently supplemented by a closed stove or hot water radiators, is maintained.

The primary essentials to success in competing with coal for these purposes are suitable characteristics, and the correct grading of coke. The desirable characteristics are relatively easy ignition, free combustibility, and low moisture and ash-content. These, in turn, facilitate kindling and continuous burning over the usual period of use in an open fire—*i.e.*, 12 to 14 hours—without undue choking.

Low ash content in coke is a matter determined mainly by the selection and treatment of the coal from which it is made; and no effort should be spared in order to attain and maintain a high standard of purity in the coal purchased for use at gas-works. The influence of this factor upon the quality of the coke produced, its suitability for competition with the very highest grades of coal for special purposes, and upon the revenue derived from its sale, cannot easily be over-estimated. Indeed, other conditions being equal, it might be laid down that the difficulty of disposing of coke in any district at remunerative prices will be in direct proportion to its ash and moisture content.

The relative combustibility of coke depends mainly upon the characteristics of the coal from which it is produced, and the manner of its carbonization; but these are matters dealt with elsewhere. Here, the main characteristics which distinguish vertical from horizontal coke need only be considered.

Vertical Coke.

The most remunerative market for coke brings it into direct competition and comparison with house or "parlour" coal, as used extensively in open firegrates. Every ton of fuel so used is usually the subject of continuous and often hypercritical examination in the results obtained. Vertical coke unquestionably gives results, especially in firegrates of the older type, which are unattainable with the denser kinds of horizontal coke burned under the same conditions.

Comparatively light and uniformly dry, vertical coke gives quicker ignition and freer combustibility; and if the widespread public prejudice against coke as a domestic fuel were analyzed, it would be found that the frequent lack of these essential characteristics in ordinary coke is the root cause of its unpopularity as a fuel for open grates.

For use in the open firegrate, vertical coke presents few difficulties. Any given set of conditions of carbonization should produce a coke of a fairly uniform description. Its special characteristics should be thoroughly investigated and understood by coke salesmen. Experiment will prove the most suitable form, as regards size or grade, that should be supplied to customers for special purposes. In the open firegrate, the aim should be to establish the grade which gives the most satisfactory all-round service, with due regard to economy. The very intensity with which coke burns in certain grates is indeed a serious difficulty; and this can be tempered only by intelligent grading and careful stoking.

Storage difficulties due to the relative bulkiness of vertical coke may be raised by users having only limited storage capacity; but this objection, as a rule, may be met and offset by the facilities offered by most gas authorities for frequent deliveries in small quantities.

Other uses for coke may render a more compact physical structure desirable; but it is well known that the density of the coke produced from any given plant may be varied considerably. Here again the aim should be to provide a fuel of the greatest general utility; and where influence can be brought to bear upon the selection of apparatus, such as hot water boilers, the use of the larger sizes, with ample fire-box capacity, should be encouraged. The large number of different types and makes of boilers now on the market gives a good deal of scope for intelligent selection in this important feature.

The Open Coke Fire.

As pointed out above, the use of vertical coke in the open fire presents little difficulty. Horizontal coke, and especially the product of heavily-charged retorts, though possessing characteristics which render it admirable for certain purposes,

is, by comparison, less tractable in the ordinary open firegrate. The subtle difference that renders certain grates eminently suitable for use with hard coke is by no means fully understood. It has been the writer's privilege to investigate the coke-burning capacities of many different firegrates; and while there appears to be no finality in special designs, essential features appear to be a suitable firebrick lining on three sides, and a sufficient depth of fuel bed. In this connection it is often remarked that coal is necessary to start a coke fire, and a strong draught is required in order to burn coke satisfactorily; that it gives off fumes; and that its combustibility is improved by the addition of moisture. No effort should be spared in order to dissipate these popular fallacies. All the draught necessary to burn coke brilliantly and satisfactorily is induced by convection currents within the fuel bed itself; the chimney draught has, in fact, very little influence upon the combustion of the fuel. To prove that this theory is correct, it is only necessary to indicate the night-watchman's coke fire, which burns well in a grate of the crudest description—usually a perforated bucket—without the aid of a chimney draught.

The use of coke as fuel in an unsuitable firegrate will not, of course, improve a tendency to down-draught; but used with any suitable firegrate that does not "smoke" when fed with coal, there should be absolutely no evidence of "fumes" from a coke fire which burns satisfactorily. In this connection it might be pointed out that the source of the "fumes"—*i.e.*, volatile sulphur—is necessarily largely driven-off in the process of high-temperature carbonization, and, in fact, is recovered as a valuable bye-product. Coke, therefore, contains less volatile sulphur than coal.

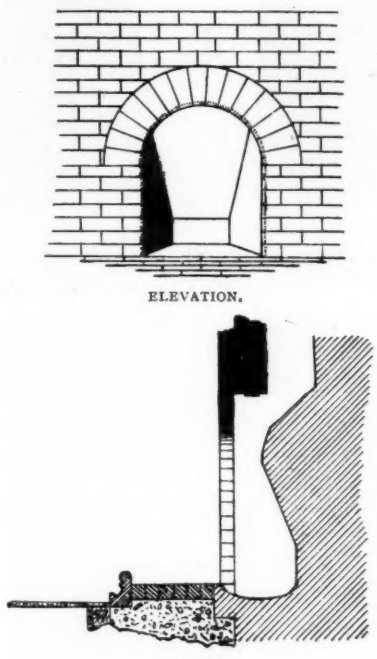


Fig. 1.—Firegrate Adapted to Burn Gas Coke on the Boys Principle.

Prof. C. V. Boys, F.R.S., has advocated the entire elimination of metal from the interior of the coke-firegrate, and also the cutting-off of access of air to the under-side of the fire. Experience has proved that grates otherwise suitable and adapted on these lines give satisfactory results with gas coke of the ordinary description. One explanation of the results obtained appears to be that less heat is dissipated, owing to the absence of metal in contact with the burning fuel; but not the least important feature of the adaptation, as the Professor has pointed out, is the fact that residual heat absorbed and retained by the firebrick sides and bottom greatly facilitates the re-kindling of the fire. That this is true there can be no doubt; and any feature of a firegrate that facilitates kindling necessarily facilitates the use of coke as fuel.

Among other grates which might be mentioned that are specially suitable for use with coke are the Well Fire Company's "Wren" interior, the "N.C." made by R. & A. Main, Ltd. (fig. 2), and the Eagle Range Company's "Hearth" grate (fig. 3), which, in addition to a firebrick bottom, is provided with means for sifting and collecting the fine ash from the fire. A coke stove of Danish manufacture, known as the "Cozy" stove, and marketed by a London firm of that name (fig. 4), is worthy of special mention. This coke stove has been submitted to, and has passed, the critical tests and examination which characterize the Good Housekeeping Institute—a recommendation which proves that it does all that is claimed for it as an economical and continuous-burning coke stove.

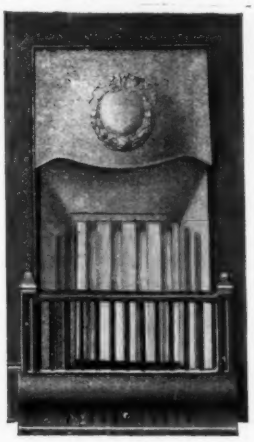


Fig. 2.—"N.C." Coke Grate (Interior).

Fig. 3.—"Hearth" Grate.

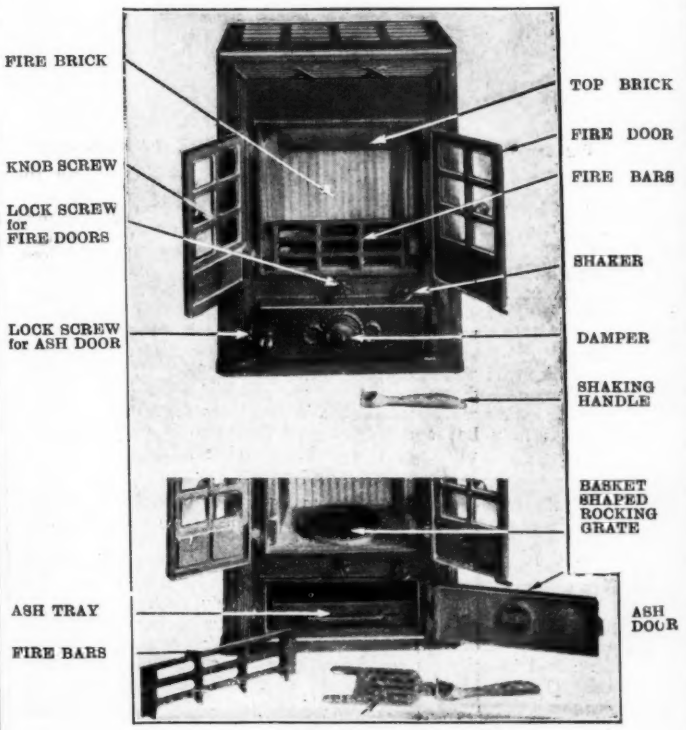


Fig. 4.—Diagram of the "Cozy" Stove, showing Removable Spare Parts.

The hinged front doors on the stove form an ever-ready "blower" which concentrates the chimney draught on the fuel bed when required. The value of the portable sheet-metal "blower" or "blazer" as a means of facilitating the kindling of a coke fire in an open grate cannot easily be over-rated; indeed, as a means of facilitating the employment of coke in open firegrates, its use should be encouraged wherever pos-

sible. The Nautilus "Kokette" fire should specially be mentioned in this latter connection.

To build a satisfactory coke fire, a certain amount of "knack" is required. In a firegrate having front bars, there is no difficulty in obtaining the necessary depth of fuel bed. In the case of the barless grate—a type increasingly popular—a "curb" or front row of large pieces of coke should be laid along the front edge of the fireplace. On this foundation a fuel bed can be built up at a high angle towards the back-brick lining. With suitably graded coke (say) from 3 in. to 4 in. pieces down to 2 in., the result is a brilliant, yet economical, fire which Prof. Boys has truly described as "the envy and wonder of all who see it."

It is neither necessary nor desirable to "poke" a coke fire, except perhaps towards the evening, and then only to raise the burning fuel with a view to allowing the fine ash to sift downwards. The original high angle and formation of a coke fire are best maintained by adding individual pieces of coke of suitable size as and when required. The dimensions of a coke fire may be diminished in the usual way, by adding side bricks; but an ordinary 16-in. fire will consume, on the average, about 2 lbs. of coke per hour, which, at 40s. per ton, costs less than ½d.

Coke for the Closed Anthracite Stove. Importance of Grading and Washing.

That coke and anthracite are interchangeable fuels with a wide difference in price is not sufficiently known. Makers of anthracite stoves of the highest class, such as Messrs. Smith & Wellstood, of Ludgate Circus, E.C., and the National Radiator Company, realizing the natural and economic limitation of anthracite, and the potentialities of coke as a means of popularizing the use of this type of stove (fig. 5), now strongly

Fig. 5.—The "Artesse" Anthracite or Coke Stove, of Messrs. Smith & Wellstood.

advocate the use of coke as an economical substitute fuel in every way satisfactory; and having regard to the large number of anthracite stoves now in use, and their growing popularity, such advocacy should receive the support which its importance deserves. But here again the matter of correct and accurate grading is fundamental to success. The grade for use in anthracite stoves of the type shown, which has been proved to be the most suitable for both ordinary use and for banking over-night, is obtained over ¾-in. and through 1¼-in. mesh. The quality, and therefore the commercial value, of this fuel is greatly enhanced by washing; indeed, some form of washing process may be regarded as indispensable in preparing the smaller grades of coke for all fuel purposes.

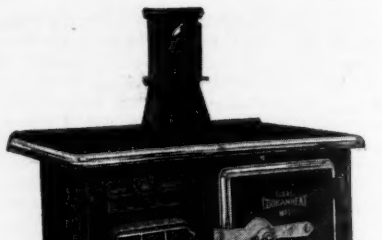
Cooking Ranges.

Similarly, anthracite cooking ranges have been found to give every satisfaction when fired with washed coke nuts (¾ in. to 1¼ in.) exclusively as fuel (fig. 6).

Coke, suitably graded to nut size, is now also used as fuel for ordinary coal-fired cooking ranges. The use of coke for this purpose, especially for hot water supply, offers a wide field for development. The introduction of a gas cooker often limits the use of the kitchen range to producing hot water for baths, &c.; and in coke we have for this purpose a fuel that is not only clean to handle, but one that is also smokeless and economical, and one which eliminates the necessity for frequent flue cleaning.

Independent Coke-Fired Hot Water Boiler.

In the domestic coke boiler we now possess a highly-developed piece of apparatus of proved economy and utility, the potential of which, from the coke-consuming point of view, is perhaps not fully realized. Having regard to the impetus which its growing popularity has already attained, and the large number of makers now concentrating upon its production, it would not be extravagant to suggest that, eventually, the domestic coke boiler will absorb the total available output of gas coke in many districts. The development of this outlet



For cooking, heating, and hot water supply, the latter being provided on the "Indirect" system with the Ideal Indirect Cylinder or Calorifier.

For hot water supply and low-pressure hot water.

Fig. 6.—National Radiator Company's "Cookanheat" and Coke Boilers.

for coke has many advantages, both practical and economic. It brings the great potential of coke, as a clean, smokeless, and relatively cheap fuel, to bear in a direction in which gas itself frequently fails on the score of cost—*i.e.*, continuous heating and continuous hot water supply. Used for these purposes, coke therefore tends materially to promote the use of gas by facilitating the use of the gas cooker and the gas fire. Supplemented by a coke boiler and hot water radiators, the convenience and labour-saving advantages of the "all-gas" house are retained with the added advantages and convenience of continuous hot water, uniform temperature, greater economy, and means for the incineration of refuse. Used for these purposes, coke, as already stated, performs its natural and obvious function as a fuel both supplementary and complementary to gas.

Economic and Practical Advantages.

The regular, continuous, and largely non-seasonal character of this potential demand for coke, and all that it implies in the stabilization of the coke market, is a matter of the first importance in the conduct of a gas undertaking. Demand should vary only in sympathy with the output of gas, and prices only in sympathy with those of competing and interchangeable fuels, which are few and relatively scarce. Coke is eminently suitable for this purpose. It is economical, lasting, readily controllable, and quick to respond to sudden demands for hot water. Bituminous coal, for obvious reasons, is unsuitable; so that the possibility of competition is limited to non-volatile fuels which are relatively expensive.

Except in the matter of correct grading, which is fundamental to success and satisfaction, coke used in boilers is subject to less competition and criticism than that used in open fires. Unavoidable variations in quality are in use less apparent; and the kindling and use of even the hardest descriptions of gas coke are greatly facilitated by reason of the concentrated draught available with all coke boilers. Indeed, the practical and economic advantages of a stabilized and adequate demand for this purpose are such that no effort should be spared steadily to promote and extend the use of the coke boiler. Hire-purchase terms, installation and maintenance, and, indeed, existing gas-selling organizations and all the facilities offered to potential users of gas appliances, should similarly be brought to bear to their fullest extent to promote the use of the coke boiler.

Types of Coke Boilers. Essential Features.

There are already several well-known types of coke boiler on the market; new and improved types are frequently being

introduced. The essential features in design are (1) large firebox capacity; (2) adequate internal cleaning facilities; (3) small floor space occupied; (4) large hotplate area; (5) convenience and control in working; and (6) facilities for open-fire working and for connecting to existing or new pipe systems. Boilers are made in both cast-iron and wrought steel, and, for equal capacities, vary considerably in price. In all cases, comparative cheapness is all-important.

As already stated, firebox capacity, for any given size of boiler, is important in order that one charge of suitably-graded coke will be sufficient to keep the fire alight over-night without attention. The importance attached to internal cleaning facilities will vary according to the characteristics of the domestic water supply in different districts; but in all cases these must be adequate and substantial, especially where maintenance is undertaken. Good selling points are general attractiveness and hotplate accommodation; though, in practice, the amount of cooking that can be done on a coke boiler is small, the limitation being the tendency to overheat the water if continuous cooking operations are attempted.

Appearance and Control.

A well-designed coke boiler should "pair" well with a gas cooker; and control apparatus should include a draught-check in the flue pipe, which serves also as an access door for cleaning purposes; a chimney damper, so formed that it cannot completely close the chimney opening, and so cause the escape of combustion products; and close-fitting fire and ash-pit doors.

In many cases importance is attached to facilities for open-fire working, especially where maids occupy the kitchen during the evenings, thus obviating the use of a gas fire where the kitchen range has been discarded.

Pipe tappings should include a draw-off tap or drain plug, to facilitate internal cleaning operations, the frequency of which will vary according to the district and whether the boiler is treated rationally or allowed to overheat and boil the water. Two flow, and two return, connections should be provided. These should be of ample diameter, so that provision can be made for the accidental accumulation of scale, by increasing the diameter in the first few feet of flow pipe, where it is most liable to collect. The two spare pipe connections facilitate the connection of radiators, the use of which in practice has been found to be perfectly satisfactory.

Advantages of Steel.

The advantages which distinguish the steel boiler, as compared with the cast-iron boiler, should carefully be noted, more especially if maintenance is to be undertaken. For use in districts where the water causes serious corrosion, both steel and cast-iron boilers may be protected by Bower-Barffing; but in any case, though the cast-iron boiler is equally efficient from the point of view of heat transmission, the steel boiler, which is not liable to fracture, would probably have the longer useful life in most districts. As a matter of insurance, in case of accident, a safety valve, preferably of the spring-loaded type, should always be fitted near the flow connection.

Standardization.

Having regard to the importance that the coke boiler and its maintenance may assume in most districts, boiler manufacturers should be encouraged to produce from the outset boilers of various standard capacities, with standardized parts interchangeable as between the various sizes of boilers, as far as possible; and to eliminate all unessential details liable to breakage and derangement. The volume of business likely to accrue entitles the gas industry to insist upon compliance with its special requirements in these matters.

Such details, for instance, as mica fronts and chimney dampers, if improperly made, are liable to give trouble. The latter, due to the formation of hard carbon scale, is liable to jamb and to become inoperative, if not provided with ample clearances. A broken mica panel upsets the draught regulation and the possibility of complete control. The entire elimination of mica would therefore be desirable; but if it must be included, facilities for its protection against damage, and for its ready replacement, must be provided. Firebars should be so designed and situated that they are not liable to burn out; and in any case they should readily be removable. A shaking firegrate facilitates the removal of fine ash, but does not deal with clinker, the formation of which is unavoidable; and it is therefore problematic whether the use of the shaking bottom, which is liable to derangement, should be encouraged.

Water-ways should be of ample sectional area and should extend well below the fire level, in order to allow for the accumulation of solid deposit without undue risk of overheating.

Coke Boiler Combinations.

Attempts have been made to combine an oven with certain makes of coke boilers, but experience in certain cases has proved that the oven can be used for cooking purposes only at the risk of overheating the water. As a hot closet, such a fitment serves a useful purpose.

Radiators.

Any coke boiler of suitable capacity, in addition to giving an ample supply of hot water, will maintain one or more radiators at a satisfactory temperature. Situated in adjoining rooms, or in the entrance hall, these radiators, combined with the heating effect of flow and return pipes and hot storage tank, maintain the atmosphere of the house at a pleasant temperature, which tends to render the continuous open coal fire unnecessary, but strongly suggests the utility and convenience of the gas fire, which can be controlled and discontinued as required.

Apart from the capacity of the boiler, one limitation to the number of radiators that may directly be connected is the tendency to discolour the water with iron-oxide, due to the rusting of the radiators; but with a moderate number this tendency is, as a rule, imperceptible. The use of a calorifier, or indirect storage cylinder, would, of course, enable any required number of radiators to be connected. (Figs. 7, 8, 9.)

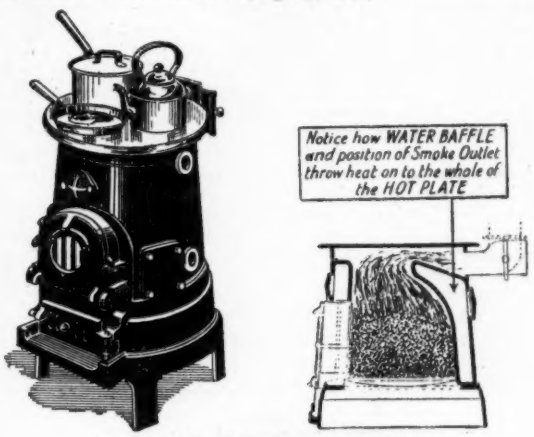


Fig. 7.—The "Glow-worm" Coke Boiler.

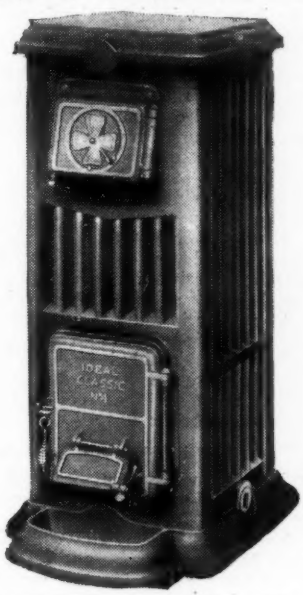


Fig. 8.—"Ideal Classic" Boiler, for Water Heating and Radiators.

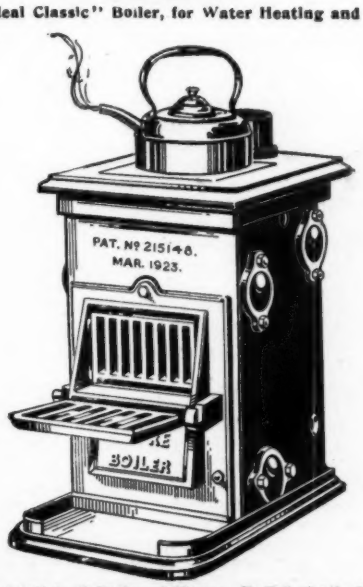


Fig. 9.—Steel "Koke" Boiler of Messrs. T. Balmforth, Ltd., Luton.

Industrial Uses.

The use of coke as fuel for central-heating boilers, and in the glass-house and other industries, is so well known that remarks on industrial uses may be confined to steam-raising. There is no type of coal-fired boiler that cannot be fired with coke, with, of course, suitable adaptation, where adaptation is necessary. The different types of stationary boilers in general use include the vertical, Cornish, Lancashire, Galloway, marine, dry-back return-tube, and locomotive boilers. These are known generally as internally-fired boilers. Externally-fired boilers include all the various types of water-tube boilers. Both kinds are again divided into "hand-fired" and "mechanically-stoked" boilers.

All internally-fired boilers have furnaces completely surrounded by water spaces which render them ideal smoke producers, when fired with bituminous coal; and, as a rule, the lower rows of tubes in the water-tube boiler are set so near the firegrate as to render it at least the equal of the internally-fired boiler in the matter of smoke production. Indeed, having regard to the large number of factory boilers in use in this country (there are over 120,000 of the Lancashire type alone) and the quantity of coal fired annually (90 million tons), the wonder is that the smoke nuisance is not more serious.

A Lancashire boiler in constant use will consume 1000 to 2000 tons of fuel per annum. Many boilers are operated at a moderate rate of output; but a large number are worked constantly beyond their normal maximum capacity. These latter are the chief offenders in the matter of smoke emission, and are probably the most difficult to adapt to coke firing.

Coke for Steam Raising.

In estimating the capacity of a coal-fired boiler to maintain the required output on coke exclusively as fuel, three factors must be ascertained: (1) The effective grate area; (2) the rate of coal consumption per square foot of grate area per hour; and (3) the draught available at the boiler furnace.

The grate area is ascertained by simple measurement. In an ordinary Lancashire boiler, the grates usually measure about 3 ft. wide by 6 ft. long, which gives 36 sq. ft. grate area, Calculation based on information given by the user will determine the maximum hourly rate of coal consumption per sq. ft.

An ordinary rate of coal consumption in boilers of this type is 4½ cwt. (504 lbs.) per hour, or 14 lbs. per sq. ft. of grate area per hour—*i.e.*, 504 lbs. ÷ 36 sq. ft. = 14 lbs.

The maximum draught available under ordinary conditions of working may be ascertained by means of a draught gauge, applied over the fire, or by means of an anemometer, applied to the ash pit. Over the fire, 0·25 in. water-gauge is a good average draught, and would correspond to about 400 to 500 ft. per minute at the boiler ash-pit. A draught of this intensity would burn 16 to 18 lbs. of suitably-graded coke per grate-foot hour; but it must be borne in mind that, whatever the draught available while burning a long-flaming coal, the draught available with coke will be considerably less, due to the lower outlet temperature of the flue gases, under similar conditions; so that due allowance must be made in estimating the coke-burning capacity of any coal-fired boiler furnace.

Evaporation per Lb. of Coke.

With a steam-jet or other system of forced draught, rates of 20 to 25 lbs. of suitably-graded coke per grate-foot-hour are maintained.

Rates up to 16 or 17 lbs. are readily and frequently maintained where there is a satisfactory natural draught; but, in practice, the actual rates attainable can accurately be determined only by a trial. In ordinary every-day practice, an average evaporation of 6 to 7·5 lbs. per lb. of coal slack is obtained; with good hard steam coal, 9 to 9·5 lbs.; and with good-quality Welsh steam coal, 10 to 10·5 lbs. per lb. of coal.

Coke of average good quality, 12,000 B.Th.U. per lb. as fired, will evaporate 9 to 10 lbs., according to conditions; so that a boiler using coke at the above rate—*i.e.*, 504 lbs. per hour—would evaporate 4500 to 5000 lbs. per hour on natural draught. With a forced-draught furnace of (say) the "Turbine" or "Wilton" type, an output of 6500 lbs. of steam can readily be maintained with coke alone as fuel.

The intense radiant effect of coke, and consequent high efficiency of heat transmission, should give a lower outlet temperature of the combustion products than that obtained with coal; and the invaluable smokeless characteristic of coke should be taken into account when comparing the cost of evaporation with different kinds of competing fuels.

Comparative Fuel Cost of Evaporation.

The fuel cost of evaporation is usally expressed as so much per 1000 gallons evaporated; and as a useful means of comparison, with a view to determining prices, the following table (Table I.), based on the figures given above, has been compiled. For example, if the competing fuel were hard steam coal at 33s. per ton, the approximate cost of evaporation may be taken as 15s. 6d. The equivalent figure for coke, according to the table, would be 31s. per ton. The comparative evaporative values given for the various coal fuels mentioned in the table are well established in first-class boiler practice, and, if anything, err on the generous side for ordinary every-day conditions. On the other hand, coke of good average quality should in ordinary circumstances evaporate rather more than 9 lbs. of water per lb. of coke, as the following daily routine test (Table II.) results tend to prove. These figures were obtained from one of the Institutions of an important Asylums Board, during the war period, and the results then obtained are well maintained at the present time.

Table I.—*Approximate Fuel Cost of Evaporation, from and at 212° Fahr., with Gas Coke and Various Competing Fuels.*

Coal Slack. Mechanically Stoked.		Hard Steam Coal. Hand Fired: Natural Draught.		Smokeless Welsh Coal. Hand Fired: Natural Draught.		Gas Coke. Hand Fired: Forced Draught.	
At per Ton.	Evaporative Value, 7·5 Lbs. Per 1000 Gallons Evaporated.	At per Ton.	Evaporative Value, 9·5 Lbs. Per 1000 Gallons Evaporated.	At per Ton.	Evaporative Value, 10·5 Lbs. Per 1000 Gallons Evaporated.	At per Ton.	Evaporative Value, 9 Lbs. Net. Per 1000 Gallons Evaporated.
s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
19 0	11 4	26 0	12 2	28 0	11 10	25 0	12 4
20 0	11 11	27 0	12 8	29 0	12 4	26 0	12 10
21 0	12 6	28 0	13 1	30 0	12 9	27 0	13 5
22 0	13 1	29 0	13 7	31 0	13 2	28 0	13 11
23 0	13 8	30 0	14 0	32 0	13 7	29 0	14 5
24 0	14 4	31 0	14 6	33 0	14 0	30 0	14 10
25 0	14 11	32 0	15 0	34 0	14 5	31 0	15 4
26 0	15 6	33 0	15 6	35 0	14 10	32 0	15 10
27 0	16 1	34 0	16 0	36 0	15 4	33 0	16 4
28 0	16 8	35 0	16 5	37 0	15 9	34 0	16 10
29 0	17 4	36 0	16 11	38 0	16 1	35 0	17 4
30 0	17 11	37 0	17 5	39 0	16 6	36 0	17 10
31 0	18 6	38 0	17 10	40 0	16 11	37 8	18 4
32 0	19 1	39 0	18 4	41 0	17 4	38 0	18 10
33 0	19 8	40 0	18 9	42 0	17 9	39 0	19 5
34 0	20 4	41 0	19 2	43 0	18 2	40 0	19 11
35 0	20 11	42 0	19 8	44 0	18 7	41 0	20 5
36 0	21 6	43 0	20 2	45 0	19 0	42 0	20 10
37 0	22 1	44 0	20 8	46 0	19 5	43 0	21 4
38 0	22 8	45 0	21 1	47 0	19 10	44 0	21 10
39 0	23 4	46 0	21 7	48 0	20 4	45 0	22 4
40 0	23 11	47 0	22 0	49 0	20 9	46 0	22 10
41 0	24 6	48 0	22 6	50 0	21 2	47 0	23 4
42 0	25 1	49 0	23 0	51 0	21 7	48 0	23 10

Table II.—*Specimen Daily Records of Coke-Fired Lancashire Boilers.*

Date.	Economizer. Inlet. ° Fahr.	Economizer. Outlet. ° Fahr.	Pounds of Water Evaporated per Pound of Coke as Fired. Actual.	Pounds of Water Evaporated per Pound of Coke as Fired. From and at 212° Fahr.
June 27	120	240	9·06	10·18
,, 28	115	225	8·31	9·35
,, 29	120	215	8·67	9·74
,, 30	120	210	8·45	9·49
July 1	120	215	8·84	9·93
,, 3	120	210	9·0	10·11
,, 4	120	230	9·38	10·45
,, 5	120	225	8·93	10·02
,, 6	120	225	9·03	10·14
,, 7	120	225	8·60	9·66
,, 8	120	240	9·16	10·29
,, 9	115	225	9·02	10·13
,, 10	115	225	9·52	9·57
,, 11	110	230	8·87	10·05
Average				9·9 lbs.

Note.—The above boiler data are taken from the boiler log sheets of an important public institution. An ordinary Lancashire boiler having 36 sq. ft. of grate area, and fired with coke exclusively at the rate of 18 lbs. per sq. ft. of grate area per hour, would evaporate, on the above basis, over 6000 lbs. of water per hour. This rate is seldom exceeded by boilers fired with ordinary low-grade bituminous coal.

B.Th.U. Basis of Sale.

In large industrial establishments there is a growing tendency to purchase solid fuels upon a guaranteed calorific power basis, or on analysis, or ash-content basis. To comply with this requirement incurs no serious difficulty; and, indeed, an offer to supply coke to customers in a position to buy on this basis tends materially to inspire confidence.

The onus of testing is necessarily placed upon the buyer, with suitable safeguards in case of dispute, a *pro rata* bonus or penalty being provided for in case the calorific power exceeds, or falls short of, the guaranteed standard. In actual practice, coke contracts based upon a guaranteed calorific power of 12,000 B.Th.U. per lb., as sold, have operated smoothly. Variations in quality naturally have occurred, but, on balance, the agreed contract price has fully been realized. Though a useful basis of comparison, the gross calorific power, as determined by a calorimetric test, is not a complete criterion of the

relative evaporative values of coal and coke. All coals contain 3 to 5 p.ct. of hydrogen, which has a calorific power of 62,000 B.Th.U. per lb. The heat which results from the burning of the hydrogen is not entirely available for performing work in the boiler; so that the difference between the gross and the net calorific values of coal may be considerable. Coke contains practically no hydrogen and no volatile hydrocarbons; compared with coal, it requires, therefore, very considerably less excess air to complete its combustion, and it has consequently a greater "availability" than coal; the difference between the gross calorific power and the net calorific power being practically *nil*.

Hand Firing.

In firing coke by hand, it is necessary to observe the simple rule that the grate should be well covered, in order to exclude air in excess of that required to effect the complete combustion of the carbon directly to CO_2, at the required rate.

A blue flame on the surface of the fire indicates that the fuel bed is too thick for the draught available; and in order to attain the maximum temperature and evaporative effect, the aim should be to regulate the fire thickness so that complete incandescence, or an orange coloured flame, is maintained. In these circumstances, the carbon is reduced almost directly to CO_2, the reaction to CO being avoided or reduced to the minimum, and only the minimum excess of air used. Needless to say, the admission to the furnace of secondary air, either at the bridge-wall or at the furnace door, should be prevented as far as possible.

Balanced Draught.

Working under natural-draught conditions, the ingress of air over the fire cannot entirely be prevented; but, with forced draught, the chimney damper can be regulated just to carry-off the combustion products and no more, so that a "balanced" atmosphere is maintained over the fire. This system of working, which is ideal from the coke-burning viewpoint, is known as the "balanced-draught" system. It has great advantages, and ensures the maximum effect and economy in firing coke by hand.

Steam-jet forced-draught apparatus (designed by the London Coke Committee), which is readily applicable to boilers of the Lancashire type, is manufactured and sold by John Thompson, Ltd., the well-known boiler makers of Wolverhampton (see drawing, fig. 10). Firebars, dimensioned according to the drawing, fig. 11, have proved eminently suitable for use with coke under natural-draught conditions; but for use with forced draught, the air spaces should be considerably less.

Mechanical Stoking.

Most mechanical stokers are designed upon a free-burning coal fuel basis, and, with few exceptions, are therefore unsuitable for use with coke alone as fuel. Considerable admixtures of suitably-graded coke or breeze may, however, be used advantageously with stokers of the "coking" type. These include the "Bennis," "Meldrum," "Vickers," and "Erith" stokers, as used mainly on boilers of the Lancashire type. Coke is often used for this purpose with a view to effecting economy and smoke abatement, and it should be graded not to exceed 1¼ in. mesh. Sprinkler, or "shovel," stokers of the "Proctor" type, as applied to Lancashire and other similar boilers, are suitable for use with similarly graded coke alone as fuel, if used in conjunction with a forced-draught furnace. Installations of this description are now in satisfactory operation at several gas-works.

The Sandwich System.

Mechanical stokers used in electric and other power stations, in conjunction with water-tube boilers, are mainly of the travelling chain-grate type. Fitted with forced draught, these stokers deal satisfactorily with coke breeze and small coke; but, as a rule, only natural draught is available. This precludes the use of coke alone, or any considerable admixture of coke, if intimately mixed with the coal; but long experience has proved that stokers of this type, adapted to operate on the patent "Sandwich" system, give satisfactory and economical results with breeze, or small coke, up to 50 p.ct. or more, according to the degree of draught available.

Perhaps the chief advantage of the Sandwich system is that it facilitates the use of relatively cheap coal slack, which often cannot be used economically by itself, and, at the same time, maintains the required output of the boilers, with a 50 p.ct. admixture of coke. In this connection, the London County Council Tramways Department, one of the most important users of coke on the "Sandwich" system, has reported officially as follows: "Owing to the increased use of coke and coke breeze, a saving of £8000 a year can be effected. Apart from the saving in money, low-grade classes of coal can be dealt with on the "Sandwich" system at a much higher efficiency than would be the case if burned separately."

The proportion of coke used is usually 50 p.ct., and the necessary adaptation to the mechanical stoker is extremely simple and inexpensive; the existing coal-feed hopper being divided, by means of an adjustable metal plate, so that the coal and coke may be fed separately by hand, or by means of separate shutes, in any required ratio, from overhead bunkers divided so that the coal and coke are stored separately.

The coke, suitably graded, is fed into the front compartment d_1 (see fig. 12), so that it enters the furnace in a layer 4 or 5 in. in thickness. From the inner compartment *d*, coal is fed on top of the coke layer in any required thickness. This serves continuously to ignite the coke as it enters the furnace.

The economic advantages of the "Sandwich" system of firing steam boilers of large capacity are now well established; it facilitates co-operation between gas and electricity supply undertakings, and tends materially towards national economy in fuel use, and smoke prevention. Its adoption in preference to the pulverized fuel system by more than one of the leading municipalities, for use in their electric power stations, places the "Sandwich" system abreast of the most modern fuel

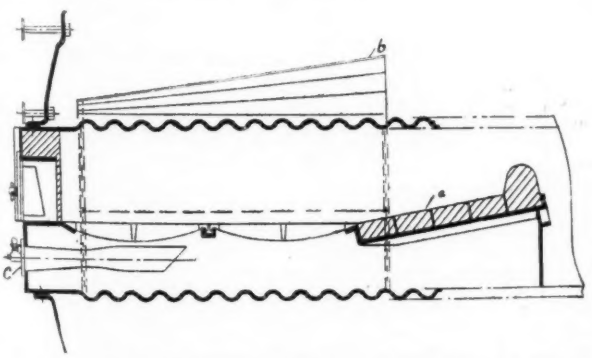


Fig. 10.—*a* Gallagher-Crompton baffle bridge, *b* Ross-Schofield circulator, *c* steam-jet forced-draught blower.

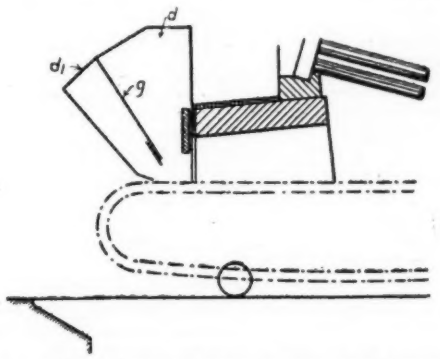


Fig. 12.—Patent Sandwich system as applied to chain-grate stoker—*d* coal hopper, d_1 coke hopper, *g* separating diaphragm.

NOTE: To find fuel cost of evaporation: $\frac{\text{Pence per ton} \times 10{,}000}{\text{water evaporated per ton.}}$

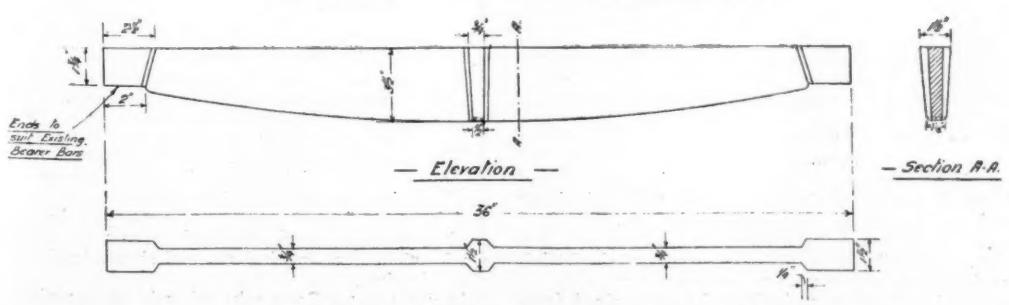


Fig. 11.—Coke Burning Fire Bar for use with natural draught.

NOTE: The overall length may be modified as required.

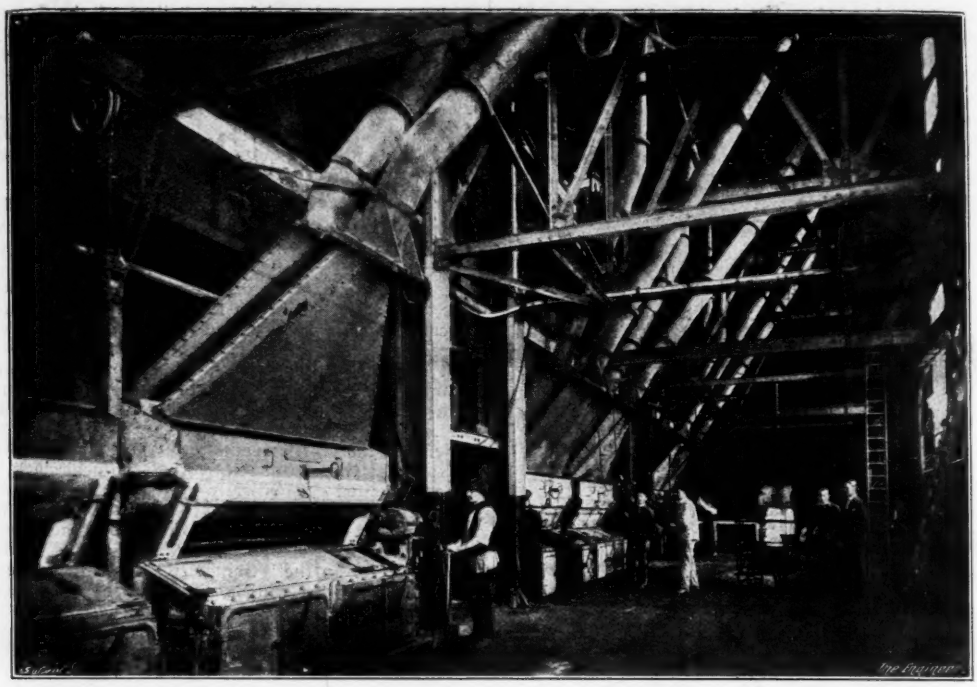


Fig. 13.—The above photograph of the interior of the Boiler House of the Barton Power Station of the Manchester Corporation has been reproduced by kind permission of "The Manchester Guardian." The separate coal and coke shutes, communicating with each mechanical stoker and with the divided coal and coke bunkers overhead, are clearly seen, as is also the dividing plate (marked "g" in the explanatory diagram) which separates the coal and coke in the feed hopper.

practice in this country, and thereby provides an outlet for surplus coke which has proved to be mutually advantageous to gas and electricity undertakings.

Results of Alternate Tests.

(1) Coal and Coke ("Sandwich" System). (2) Coal Only.

—	Test No. 1. Coal and Coke.	Test No. 2. Coal Only.
Calorific power as fired	11,138 B.Th.U.	12,150 B.Th.U.
Fuel consumed per grate foot hour	30·66 lbs.	31·66 lbs.
Ash and clinker, actual	16·22 p.ct.	12·7 p.ct.
Average steam pressure	178 lbs.	179 lbs.
Superheat temperature	486° Fahr.	490° Fahr.
Water evaporated per hour	10,505 lbs.	8,747 lbs.
Water evaporated per square foot of heating surface	5·22 lbs.	4·35 lbs.
Water evaporated per lb. of fuel as fired, from feed temperature	7·18 lbs.	5·76 lbs.
Water evaporated, from and at 212° F.	9·22 lbs.	7·44 lbs.
Efficiency, boiler and superheater	69·9 p.ct.	53·12 p.ct.
Efficiency, boiler with economizer	79·96 p.ct.	60·98 p.ct.
Draught over fire	0·25 in.	0·25 in.

From the above figures it will be observed that not only is the thermal efficiency of the boiler plant very materially improved by using the composite fuel, but the evaporation per pound of the mixture, though of lower calorific power, is higher than that of the coal only; and, moreover, the output of steam per boiler is greater by 20 p.ct.

Conducting a Boiler Test.

As a means of determining scientifically the relative commercial and economic values of coal and coke, the steam-raising test is generally regarded as perfectly reliable and acceptable among all classes of industrial users. In such a test, both fuel and water actually used in the boiler over a given period can be measured within very fine limits of accuracy by means of scales and tanks; so that the hourly output of the boiler, the evaporation per lb. of fuel, and the fuel cost of a given weight of steam, can be assessed by simple calculation, nothing being left to chance or guesswork.

Comparatively few boiler plants are fitted with the apparatus necessary to conduct a boiler test, which include a feed-water meter or calibrated tanks for measuring the boiler feed; scales for weighing the fuel used and the ash and clinker withdrawn from the boiler furnaces; thermometers; pyrometer; and CO_2 indicator.

Usually, a close estimate of the relative value of coal and coke can be made where the daily load on the plant is fairly constant, and the daily coal consumption can be ascertained from the quantities delivered, by means of a trial run of a few days' duration. The coke fired during a given period of trial, preferably under the supervision of a competent representative from the gas undertaking, can similarly be ascertained from deliveries.

In organizing a coke test on scientific lines, for the purpose of accurate comparison with results obtained with coal, it is necessary to observe certain rules. The fires should first be thoroughly cleaned, and coke fires established to maintain the load on the boiler; the level of the fires being noted, and also the level of the water in the boiler gauge glass, so that similar levels can be made to coincide with the end of the test. Feed-water meter readings and temperatures should be taken, the steam pressure noted, and quality of fuel fired, every half-hour. The duration of the test should be about 8 hours, or such period as is necessary or convenient to comply with working load conditions.

If the testing instruments available permit, the boiler flue outlet temperature and the CO_2 content of the flue gases should be ascertained frequently during the test, as these data invariably should show coke to advantage, as compared with bituminous coal.

In this connection, it has been found of great service to have one of the steam boilers at the gas-works fitted with the necessary testing apparatus, so that tests can be carried out frequently to determine the net evaporative value of the coke produced in the works, and to demonstrate to prospective users the utility of coke, both as regards capacity and economy.

Export Trade.

It would be difficult to over-rate the importance of the export market for coke, especially to those undertakings possessing facilities for direct shipment, and its bearing upon the stabilization of the home market. Influence in promoting trade is mainly one of price adjustment relative to competing fuels, and cannot therefore be dealt with here. Coke free from smalls, which are unsaleable in the Scandinavian markets, is naturally preferred by importers; but, above all, the fact that coke purchased for shipment is bought by weight and sold by measure should be borne in mind. Coke that "measures" well is therefore much sought after by importers; and due regard to such matters as quenching, physical density, and the screening of coke intended for shipment abroad will inevitably influence and secure preferment.

Advertising Coke.

As in all other saleable commodities, the efficacy of judicious advertising and competent salesmanship as a means of promoting the use of coke cannot be gainsaid. Coke advertisements may be divided into two classes—those which advertise coke and its advantages, and those which advocate the use of coke-consuming appliances. The former are intended mainly to appeal to potential industrial users to whom coal and coke are interchangeable fuels. The latter are designed to interest and influence householders. Collectively, coke advertisements tend to influence municipal authorities interested in enforcing smoke abatement regulations, and should be drafted with this object in view.

In designing a Press coke advertising campaign, the allocation of expenditure as between industrial or trade papers, and

domestic or daily papers, should first be considered and decided. Advertisement copy for trade journals should preferably be highly technical in tone, and supported by suitable paragraphs or articles relating to the subject of economy in fuel practice, and smoke prevention. Copy for use in domestic journals is more amenable to treatment in popular style, and should preferably be illustrated, attention being directed to the practical and economic advantages of the coke-fired boiler, the open coke fire, and the coke stove. One difficulty experienced has been to prevent waste circulation by locating or restricting Press advertising to one's own district of supply, so far as possible; as, obviously, coke cannot advantageously be sold except in the immediate neighbourhood of production. Posters displayed on delivery vans and hoardings have therefore been used to promote coke sales, and these, suitably designed, should prove to be an effective means of advertising coke and coke-burning appliances.

In drafting copy for use on posters, the value of the catch phrase or "slogan" should be borne in mind, with a view to emphasizing the chief characteristics of coke and its uses. The following suggestions are offered:

(1) MAKE LESS SMOKE—
USE MORE COKE.

(2) COKE & ECONOMY
"GANG TH'GETHER."

or the following adaptation from one of the lesser poets might be considered:

"TWIN Notes Inseparably Paired"
COKE & CONSTANT
HOTWATER.

For use on the reverse side of business cards, or on postcards, the following might be considered suitable for use in the industrial field:

Approximate Economy Resulting by Substituting Smokeless Gas Coke for Steam Coal in Boiler Furnaces.

NOTE.—Calculated from Results obtained in Everyday Boiler Practice.

Best Steam Coal (9·5 Lbs. per Lb.) at per Ton.	Gas Coke (Evaporative Value 9 Lbs. per Lb.) at per Ton.				
	s. d. 30 0	s. d. 30 6	s. d. 31 0	s. d. 32 0	s. d. 33 0
s. d.	Economy effected per ton of coal now used.				
38 0	6 4	5 10	5 3	4 3	3 2
40 0	8 4	7 10	7 3	6 3	5 2
42 0	10 4	9 10	9 3	8 3	7 2
44 0	12 4	11 10	11 3	10 3	9 2
45 0	13 4	12 10	12 3	11 3	10 2
46 0	14 4	13 10	13 3	12 3	11 2
48 0	16 4	15 10	15 3	14 3	13 2
50 0	18 4	17 10	17 3	16 3	15 2

A Lancashire boiler uses 1000 to 2000 tons per annum.

The figures may be varied to suit local conditions and prices according to the table given previously.

CONCLUSION.

Inferences to be drawn from the foregoing observations on the subject of developing coke sales include the following:

Coke's chief function should be to facilitate and promote the use of gas as a domestic fuel, by performing heating operations for which gas is too expensive, and by contributing the maximum revenue towards reducing the price of gas. Used for these purposes, coke does not compete with gas as a domestic fuel. As fuel for continuous hot water supply and heating, by means of the independent hot water boiler, coke is most likely ultimately to find the most remunerative and continuous outlet. Anthracite and coke are interchangeable fuels. The correct grading and screening of coke for special purposes is fundamental to success and satisfaction.

Coke graded by means of screens to the smaller sizes should be washed, to eliminate impurities.

Local conditions are no bar to the development of a satisfactory market for coke.

For open fires, vertical coke is more suitable than the denser kinds of horizontal coke.

Low ash and moisture content facilitates the disposal of coke, and materially enhances its commercial value.

A strong chimney draught is not necessary to burn coke in an open fire.

Coke burns well in a firegrate with a firebrick bottom, having no access of air to the underside.

The provision of a "blower" facilitates the kindling of a coke fire.

Steel coke boilers with large firebox capacity are to be preferred, if maintenance is to be undertaken.

Coke can advantageously be used on any type of steam boiler which is not overloaded.

Coke may advantageously be sold on a guaranteed calorific value basis.

A works boiler should be fitted-up for demonstration purposes.

Gas offices, to which the public have access, should be fitted with coke-burning firegrates and coke boilers, which should be in continuous operation, so far as possible.

APPENDIX I.—Comparative Cost of Heating Water by Coke and Electricity.

On a cost and efficiency basis, coke and electricity as agents for heating water for domestic purposes may fairly be compared as follows:

The heat equivalent of the Board of Trade electrical unit is given by various authorities as from 3400 to 3440 British thermal units. Allowing the figure generally accepted—*i.e.*, 3420 (3412 B.Th.U. is the value adopted by the Institute of Electrical Engineers)—the B.O.T. units per therm would be 29·24. Applied to water heating in modern apparatus, the efficiency of electricity may be as high as 100 p.ct.

Taking the gross calorific value of gas coke of average quality as 12,000 B.Th.U. per pound, 8·33 lbs. would equal one therm. The thermal efficiency of an ordinary domestic coke boiler, working at full capacity, is of the order of 65 p.ct. Working normally, the efficiency would be about 50 p.ct. more or less, according to conditions.

Based upon the above figures, the following table gives approximately the relative cost, per therm, of coke and electricity at various prices; and assuming radiation losses from the coke boiler and water heater to be the same in either case, the comparative cost of heating 100 gallons of water 100° Fahr. (from 50° to 150° Fahr. or 100,000 B.Th.U.) by means of electricity and coke would be as shown:

Electricity.			Coke.		
Price per Unit.	Price per Therm.	Cost per 100,000 B.Th.U. into Water.	Price per Ton.	Price per Therm.	Cost per 100,000 B.Th.U. into Water.
d.	d.	d.	s.	d.	d.
½	7·125	7·125	36	1·63	3·26
½	14·62	14·62	38	1·69	3·38
1	29·24	29·24	40	1·80	3·60
2	58·48	58·48	42	1·89	3·78
3	87·72	87·72	44	1·96	3·92
4	116·96	116·96	45	2·00	4·00

During the winter months, the average daily coke consumption for hot water supply and partial central heating in a fair-sized establishment would be about 1 cwt. (2s. at 40s. per ton), or 13·44 therms. The equivalent cost of electricity at ½d. per unit would be 8s. 2d.

Relative Cost of Heating with Various Fuels and Appliances.*

The accompanying schedule has been prepared on the basis of the number of British thermal units obtained for 1d. with the fuels and appliances in general use. To meet conditions in different parts of the country, calculations are given for a number of different prices.

	Heat Units Obtained for 1d.
Electricity.—The heat equivalent of one Board of Trade unit is here taken at 3400 B.Th.U. Assuming an efficiency of 100 p.ct.:	
At 1½d. per B.O.T. unit, 1d. purchases $\frac{3400}{1\cdot5}$ =	2,266
,, 2d. ,, ,, ,, ,, ,,	1,700
,, 2½d. ,, ,, ,, ,, ,,	1,360
,, 3d. ,, ,, ,, ,, ,,	1,133
,, 3½d. ,, ,, ,, ,, ,,	972
Gas Fires.—Taking the average calorific value of coal gas at 475 B.Th.U. per c.ft., and assuming 60 p.ct. efficiency:	
At 8d. per 100,000 B.Th.U. (therm), available B.Th.U. being 60,000, 1d. purchases $\frac{60,000}{8}$ =	7,500
At 8½d. per therm, 1d. purchases	7,059
,, 9d. ,, ,, ,, ,,	6,666
,, 9½d. ,, ,, ,, ,,	6,316
,, 10d. ,, ,, ,, ,,	6,000
Gas Radiators.—Assuming 100 p.ct. efficiency and gas at 8d. per therm, 1d. purchases $\frac{100,000}{8}$ =	12,500
At 8½d. per therm, 1d. purchases	11,765
,, 9d. ,, ,, ,, ,,	11,111
,, 9½d. ,, ,, ,, ,,	10,526
,, 10d. ,, ,, ,, ,,	10,000
Open Fires.—Taking the average calorific value of bituminous (house or soft) coal at 12,750 B.Th.U. per lb., and assuming 20 p.ct. efficiency:	
At 35s. per ton, available B.Th.U. being 12,750 × 2240 ÷ 20 p.ct. = 5,712,000, 1d. purchases $\frac{5,712,000}{420}$ =	13,600
At 40s. per ton, 1d. purchases	11,900
,, 45s. ,, ,, ,, ,,	10,578
,, 50s. ,, ,, ,, ,,	9,520
,, 55s. ,, ,, ,, ,,	8,655

	Heat Units. Obtained for 1d.
Hot Water Radiators.—Taking the average calorific value of gas coke at 11,400 B.Th.U. per lb., and assuming 70 p.ct. efficiency:	
At 30s. per ton, available B.Th.U. being 11,400 × 2240 ÷ 70 p.ct. = 17,875,200, 1d. purchases $\frac{17,875,200}{360}$ =	49,653
At 35s. per ton, 1d. purchases	42,560
,, 40s. ,, ,, ,, ,,	37,240
,, 45s. ,, ,, ,, ,,	33,102
,, 50s. ,, ,, ,, ,,	29,792

EXAMPLE.—If a room measuring (say) 14 ft. by 14 ft. by 9 ft. 6 in. high requires on an average 74,000 heat units per day of 24 hours to ensure in it a temperature of 60°, the cost of maintenance based on the above figures will be:

Electricity at 2½d. per unit	74,000 ÷ 1,360 =	54·4d.
Gas fires—gas at 9d. per therm	74,000 ÷ 6,666 =	11·1d.
Gas radiators—gas at 9d. per therm	74,000 ÷ 11,111 =	6·6d.
Open fires—coal at 45s. per ton	74,000 ÷ 10,578 =	7·0d.
Hot water radiators—coke at 40s. per ton	74,000 ÷ 37,240 =	2·0d.

Coke burned in a modern cast-iron hot water boiler yields about 8500 B.Th.U., and anthracite coal about 9400 B.Th.U., per lb.

APPENDIX II.—Comparison of Values of Oil, Coal, and Coke as Fuel for Central Heating or Steam Raising.

In large central heating installations ordinary steam boilers are often used in which, with the necessary furnace alterations, oil, coal (bituminous or anthracitic), or coke could be used as fuel; but where the boilers are of the sectional cast-iron type, smokeless coal and coke are the fuels generally preferred. In comparatively new installations, designed primarily for use with oil fuel, no provision is made for the necessary storage of solid fuel and for the removal of ashes. In such cases solid fuel could not readily be employed. Oil, coal, and coke are therefore not always interchangeable fuels; but for the purpose of comparing the probable fuel cost of heating with liquid and solid fuels, the following rough estimates may be useful. These estimates, based upon recent contract rates and prices given by representative suppliers and users of fuel, are:

—	Per Ton Delivered.
	s. d.
Coke	33 6
Leicestershire steam coal	37 6
Notts. hard ,, ,,	40 6
Smokeless Welsh navigation steam coal	43 6
Petroleum fuel oil, standard Mexican	85 0

Assuming the above-mentioned fuels to be of good average calorific power, the relative cost, on a thermal value basis, would be approximately:

—	B.Th.U. (Gross) per Lb.	B.Th.U. per 1d. of Cost.
Coke	12,000	66,000
Leicestershire steam coal	13,000	65,000
Notts. hard ,, ,,	14,000	59,600
Smokeless Welsh navigation steam coal	14,500	62,300
Petroleum fuel oil, standard Mexican	18,400	40,000

Fired under conditions most suitable for each class of fuel, the following average net evaporative values may be taken as approximately representative, although the figures given for oil (16 lbs.) should be regarded as exceptional, and realized only under full-load conditions in large-capacity steam generators; 14 lbs. to 15 lbs. being the normal evaporation obtained:

—	Evaporation per Lb. of Fuel from and at 212° Fahr.
	Lbs.
Coke	9·0
Leicestershire steam coal	9·0
Notts. hard ,, ,,	9·5
Smokeless Welsh navigation steam coal	10·5
Petroleum fuel oil, standard Mexican	16 0

Based upon the above data, the comparative fuel cost of evaporation with coke, coal, and oil would be approximately:

—	Fuel Cost per 1000 Galls. Evaporated.
	s. d.
Coke	16 7
Leicestershire steam coal	18 7
Notts. large hard ,, ,,	19 0
Smokeless Welsh navigation steam coal	18 5
Petroleum fuel oil, standard Mexican	23 8

In the above comparison no allowance has been made for the cost of ash removal in the case of the solid fuels. In cases where ashes are not removed free of charge by municipal authorities, due allowance for cartage, according to circumstances in individual cases, would have to be made in comparing coke and other fuels. In many cases, smokeless conditions of combustion in heating installations are essential. In such instances competition would be confined to coke and Welsh coal, which may be regarded as equally smokeless, and petroleum fuel oil, which, as a rule, can be fired without the emission of visible smoke, except in cases where boilers are forced beyond their normal evaporative capacity.

Combined Oil and Coke Firing.

In certain circumstances, where it is necessary frequently to force steam boilers beyond their normal capacity, and at the same time to prevent the emission of smoke, the use of oil fuel in combination with coke has successfully been adopted. This system of firing, known as the Urquhart system, has given the following certified results in recent tests:

—	Average Fuel Cost per 1000 galls. Evaporated.
	s. d.
Oil at 90s. per ton and coal (10 to 20 p.ct. oil)	17 5½
Oil at 90s. per ton with gas coke (10 to 20 p.ct. oil)	15 0

The coal and coke used were charged at the same price, and the rate of evaporation per (Lancashire) boiler frequently reached 800 gallons (8000 lbs.) per boiler per hour. This system of firing enables sudden demands for steam, as are frequently necessary in the dyeing and other similar industries, to be met without the risk of smoke emission, thus obviating the necessity for capital expenditure in increasing boiler plant in order to meet growing demands for steam.

APPENDIX III.—Heat Value and Combustion of Fuels.*

In considering the question of fuel values, the carbon and hydrogen may be taken as the "fuel substance;" these elements providing practically all the heat produced by the combustion of the fuel. Sulphur is present as either sulphates or pyrites, or both; but only pyrites has any combustible value (and even that is very small), as the sulphates remain in the ash. The following table gives the heat combustion values:

Element.	Formula.	Products of Combustion.	Heat of Combustion.
			B.Th.U. per Lb.
Hydrogen	H_2O = H_2O gas	Steam	52,200
	liquid	Water	62,100
Carbon	C O = CO gas	Carbon monoxide	4,350
Carbon	C O_2 = CO_2 gas	Carbon dioxide	14,540
Sulphur	S O_2 = SO_2 gas	Sulphur dioxide	3,895

Hydrogen is present in coal in combination with carbon as hydrocarbons which, being of a volatile nature, have a tendency to pass quickly out of the boiler furnace in a partially-burnt state, usually resulting in an excessively high stack temperature, and consequent serious loss of heat. The fixed carbon—that is, the carbon which is free, not combined—is very efficiently oxidized to carbon dioxide in the firebox of a boiler. It will be noted from the above table that, when carbon is imperfectly burnt, carbon monoxide results, and only 30 p.ct. of the potential heat is generated. Thus, although hydrogen has a much higher heat potential than carbon, the most important fuel substance is free or "fixed" carbon, and the most suitable fuel for use in central heating boilers is one in which the chief heat-producing element is carbon. For this reason, in addition to the danger of explosions occurring under certain firing conditions, and the sooting of heating surfaces, bituminous or soft coal is less suitable than coke or anthracite coal.

Anthracite, gas coke, and furnace coke contain very little volatile combustible matter, as the following table shows, and are therefore the most useful fuels for heating boilers. It must be understood that fuel can vary considerably, even from the same district; and the figures given must therefore be taken as approximate.

Fuel.	Fixed Carbon.	Volatiles.	Ash.	Moisture.	Sulphur	Calorific Value B.Th.U. per Lb.
High grade bituminous coal	40·60	28·40	4·10	2·6	1·3	12,000—13,500
Semi-anthracite	70·84	10·15	4·10	2·6	1·2	12,000—14,000
Anthracite	80·90	3·7	3·8	2·4	1·2	12,600—14,200
Gas coke	70·88	1·5	7·18	3·10	1·3	10,200—12,600
Furnace coke	76·88	1·2	8·14	3·8	1·4	11,000—12,800
Lignite (brown coal)	19·30	30·45	3·11	15·45	15·3	5,600— 9,200
Peat (air dried)	18·26	50 60	2·8	15·20	..	4,500— 7,000
Peat (artificially dried)	50·65	28·38	3·10	..	..	7,500— 9,000
Wood (air dried)	..	..	1·4	15·20	..	4,200— 5,600
Wood (artificially dried)	..	..	2·6	2·4	..	6,000— 7,200
Wood charcoal	75·85	4·8	6·9	5·9	..	10,600—11,200
Fuel oil (residual)	..	..	..	..	1·3	18,000—19,000

Coal gas . . . . . 450—550 B.Th.U. per c.ft.
Producer gas . . . 120—150 ,, ,, ,,

The relative density of fuels is important, as in combination with the calorific value it determines the available heat to be derived from one charge in any boiler. The thermal efficiency of central heating boilers may be taken as 50 to 70 p.ct., according to conditions of use.

Approximate densities, total heat per cubic foot, and available heat for anthracite and coke are given in the following table:

Fuel.	Density per C.Ft. Lbs.	Average Value. B.Th.U. per Lb.	Total Heat per C.Ft. B.Th.U.	Net Available Heat per C.Ft., Allowing 70 p.ct. Boiler Efficiency B.Th.U.
Anthracite . . .	50	13,400	670,000	469,000
Gas coke . . .	25	11,500	287,500	171,050
Furnace coke . .	30	11,900	357,000	212,400

* National Radiator Company.

APPENDIX IV.—The Independent Coke Boiler; Working and Installation Errors.

The growing popularity of the independent hot water boiler is probably the most convincing evidence of its success as an economical and convenient domestic appliance. Experience proves, however, that not infrequently difficulty and disappointment arise from small errors of judgment in connecting the boiler flue-pipe to existing chimneys and flues. And, again, the makers' working instructions are often disregarded, or misunderstood, with the result that trouble and inefficiency are wrongly attributed to the coke boiler itself, when the grading of the coke, method of working, or connecting are really at fault. The metal flue pipe which connects the boiler to the kitchen chimney is, for instance, a common, but unsuspected, source of trouble, adversely affecting the draught, and consequently the output or capacity of the boiler.

All domestic coke boilers are fitted with a damper placed immediately under the smoke nozzle or outlet to the flue. The obvious intention of the boilermaker (which, however, is not always mentioned in his list of instructions) in providing this nozzle is that it will be inserted inside the metal flue pipe, which usually is provided by the hot water fitter, thus ensuring an ample flue area, and consequently a good draught. Experience shows that this flue pipe is often provided too small in diameter, and is inserted inside, instead of outside, the smoke nozzle, with results that frequently lead to disappointment or complete failure of the installation. A flue pipe so fitted is not only too small in sectional area to ensure the maximum output of the boiler when required, but its weight is often thus caused to rest upon the damper, which in consequence cannot be operated properly to control the fire.

Another common flue pipe defect is the lack of adequate cleaning facilities. If soft coal should be used as fuel, or even for kindling the coke fire, as it is frequently but quite unnecessarily used, the deposit of soot in the metal flue pipe is surprisingly rapid and effective in obstructing the draught. A few days' firing with soft coal has, in fact, been known to reduce the effective area from 4 in. to 1 in. diameter.

If coke only is used as fuel, the need for the frequent use of the flue brush disappears; but, nevertheless, one access door should always be provided, however short the flue pipe, with additional access doors at all bends or elbows.

Hot water boilers are, again, often connected to existing kitchen chimneys which serve also the kitchen range, which may or may not be in constant use. In such cases, neglect simply to close the chimney dampers of the kitchener has led to loss of available draught at the boiler flue, and the recording of serious complaints against the vendors of the coke used and the makers of the boilers. Probably the most frequent cause of difficulty and annoyance is the use of unsuitably graded coke. Having regard to the relatively small capacity of the boiler firebox, the fuel should be graded evenly to a size not exceeding about 1¼ in. Obviously, larger sized coke cannot be accommodated in sufficient quantity, and its use not merely necessitates almost constant attention, but leads also to inefficiency and frequent and unnecessary re-kindling of the fire.

Although all boiler makers rightly claim that their boilers will consume either coal or coke, it is not sufficiently emphasized that smokeless or anthracitic coal is meant. The use of ordinary soft or household coal is, as already pointed out, singularly detrimental to the boiler. Used in the firebox, which is surrounded with cold or relatively cool water, the volatile gases evolved from such coal quickly condense on the firebox walls or heating surfaces, thus rendering them inefficient. As a cursory examination will show, the heating surfaces become coated with a hard, black carbon shale, difficult to remove, and possessing a heat insulating power of six times its thickness of asbestos.

Due attention to these apparently minor, but really most important, details from the outset of a coke boiler installation should lead to the full enjoyment of an adequate, constant, and relatively inexpensive supply.

SECTION III.—GAS COKE AS A DOMESTIC FUEL.—(*Continued*).

Third Award, won by "F.W.S."

BY MR. F. W. SMELTS, BRITISH COLUMBIA ELECTRIC RAILWAY COMPANY, VANCOUVER, B.C.

SALE, DISTRIBUTION, AND USE OF COKE.

Since the year 1916, our coke production has shown a yearly increase from 2534 tons to 20,000 tons for the year ending June 30, 1925. This rapid increase necessitated the organization of a Coke Sales Department, and the development of aggressive sales methods, in order to enable us to dispose of the yearly make of coke. The above figures include both coke and breeze production. The coke is separated into different sizes as shown in fig. 1. In order to increase the revenue from the breeze, the Company recently installed an ovoid briquetting plant of the roller-press type, with an output of 20 tons per eight-hour day; and in the future all coke breeze will be converted into briquettes and marketed as such. Figs. 2, 3, and 4 show the briquetting plant, the press, and the actual size of the briquettes.

MARKET AND USE OF COKE.

The city, with a population of 225,000, constitutes our most important market, though occasionally we make shipments by rail or water to outside points. The local market consists of the following:

1.—Iron works, where coke finds use in the core ovens; the size preferred being lump coke.

2.—Apartment houses and large public buildings:

A.—Low-pressure steam installations, which use a 50-50 mixture of coke breeze and coal slack.

B.—High-pressure steam installations. The same as under "A."

C.—Hot water installations. Any size of coke from lump to breeze, mixed with varying proportions of nut coal or coal slack.

D.—Hot air installations. Mostly lump coke and lump coal or nut coal is used in plants of this particular type.

3.—Bakers. For portable ovens and brick ovens, lump coke is the favourite fuel. At least 95 p.ct. of the local bakeries are using coke.

4.—Greenhouses. These plants are heated entirely by hot water "Robin Hood" type furnaces. Lump coke is used exclusively.

5.—Poultrymen. Both nut coke and briquettes are used in small brooder stoves.

6.—Miscellaneous industries:

A.—Galvanizing works,
B.—Carbonic acid gas works.
C.—Candy manufacturers.
D.—Blacksmiths.

All these prefer lump coke, with the exception of the blacksmiths, who utilize nut coke.

7.—Householders:

A.—Fireplace. Lump and egg-sizes of coke and briquettes are widely used.

B.—Kitchen ranges. Nut coke and briquettes.

C.—Hot air furnaces. Egg-size or lump coke or briquettes make the ideal fuel. In cases where the operator in charge of these furnaces is thoroughly versed in the use of coke, 25 p.ct. of breeze can be added to the coke and burned efficiently and satisfactorily.

D.—Hot water furnaces. The same as under "C."

E.—Heaters.—The same as under "C," except that the addition of breeze is not desirable.

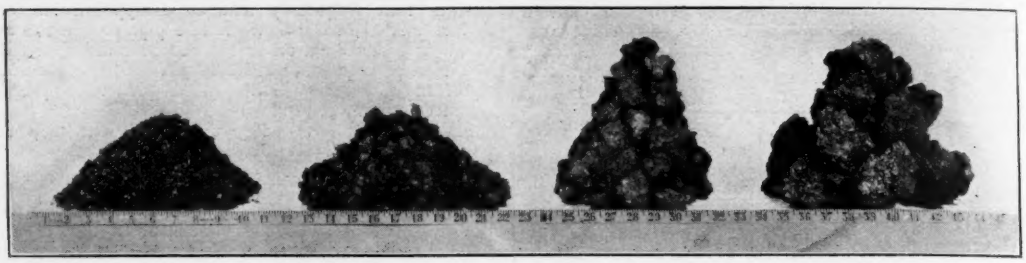


FIG. 1.—COKE SIZES.

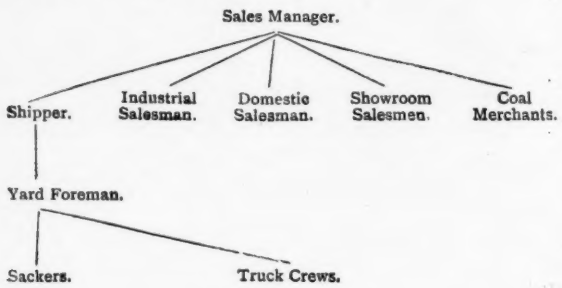
Competition.

Periodically the local fuel market is flooded with large amounts of cheap mill-wood, ranging in price from $4 to $7.50 per cord. There are also in the neighbourhood a number of lignite coal mines, which ship to the local market at prices from $8 to $9 per short ton. Non-coking bituminous coal slack sells at $5 per ton, while the domestic sizes bring from $10 to $11. Coking bituminous coal sells from $6 per short ton for slack to $11 per short ton for lump coal. Coke is sold for $11 per ton delivered, and the breeze for $6. All these prices are delivered into the customer's basement.

When the Company were faced with the problem of finding an outlet for the rapidly increasing output of coke in the face of the stiff competition from other fuels referred to, two solutions presented themselves. One was to follow a price-cutting policy; the other, to make a stronger sales effort, and if possible maintain the prices. The management decided on the latter policy—very wisely so, as subsequent events showed. It was fully realized that a cut in prices would have to be considerable to stimulate buying to any large extent; that its effect would last for only a short time; and that it would seriously affect the net returns from the coke.

Sales Organization.

The first step taken was to increase the price of coke, so that the added expenditure, caused through aggressive sales efforts, would not materially affect the net returns. The next step was the organization of a separate Coke Sales Department along the following lines:



As the chart shows, the Sales Manager personally looks after the local fuel merchants, who heretofore were very much opposed to the sale of coke.

At one of their weekly meetings, these merchants were addressed, and the coke situation frankly put before them. We explained how the increased demand for gas meant increased production of coke. This coke had to be sold, and most of it on the local market. If we were not able to dispose of it at the present price, we would have to cut prices and dump a large

Fig. 2.—Briquetting Plant.

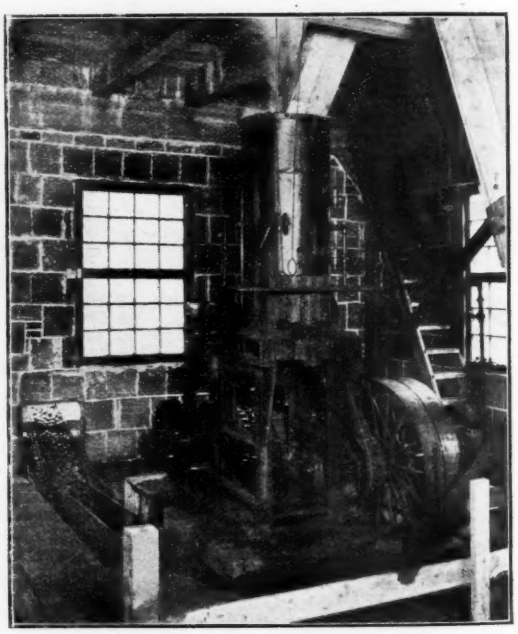


Fig. 3.—Briquetting Press.

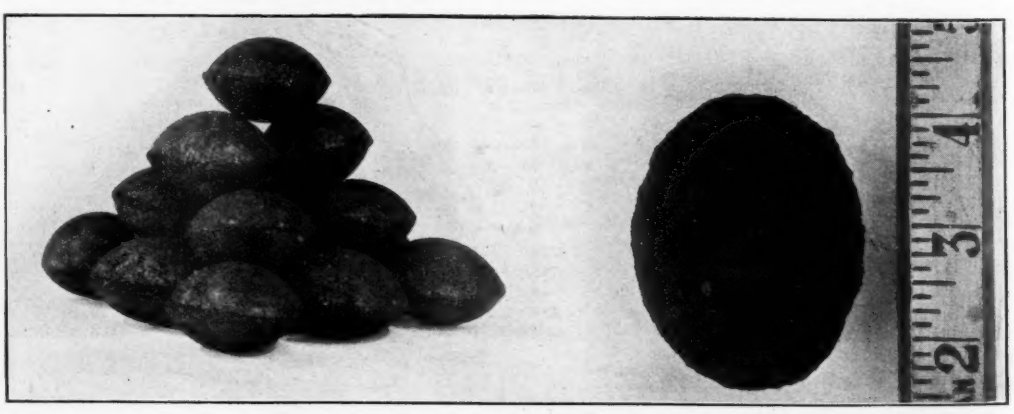


FIG. 4. BRIQUETTES.

tonnage on the market at whatever price would move our stock. However, we hoped to avoid this, and expected to be able to maintain prices if they were willing to co-operate with us. We offered these merchants an introductory margin of $4 per ton, undertook to teach their salesmen, and also agreed to have our own men make free demonstrations to the merchant's customers whenever called for. The coal merchants promptly fell in line. They did not get much additional business, and, as a matter of fact, a number of our old customers, who for years had bought from us direct, bought through some dealer friend. But the important advantage was that we stopped opposition from the dealers, and have ever since worked in close co-operation with them.

The Sales Manager also looks after out-of-town fuel merchants. This was of great importance at the start of our campaign, as such business was quickly worked-up in a large enough volume to reduce our stocks somewhat.

The coke yard crew and the delivery trucks, who were formerly responsible to the Superintendent of the plant, now report to the Coke Sales Manager, because it is absolutely essential that the men looking after the preparation and the delivery of the coke are thoroughly acquainted with the view-point of the customers.

We have tried out different methods of working and paying salesmen, and have adopted the one that proved most successful. One salesman looks after all industrial customers, and another salesman handles the domestic business. We find that it takes entirely different types of men for these two jobs; and we also use different sales appeals. In the industrial field, economy and price appeals bring the best results; while in the domestic field, cleanliness is the major attraction.

During special campaigns, we sometimes employ a few additional men, who are paid a commission of 50c. per ton on all orders turned in by them. The regular salesmen are paid a salary and commission of 10c. per ton on all orders that come in from the particular class of business they look after.

The Company operate four showrooms in different parts of the city, where gas and electrical appliances are sold. At each of these showrooms is at least one qualified man—usually the man in charge of the gas appliances—taking orders for coke. A coke display attracts inquiries, and this man is right on the spot to give a selling talk and take the orders.

Selling Points and Objections.

The following will give a short outline of the main talking-points we use in selling coke, and also of the chief objections we meet and how we strive to overcome them.

Advantages of Screened Coke, Smokeless.—Coke is smokeless, and therefore more efficient than bituminous coal. Smoke represents tremendous economic waste. No household heating appliance has been manufactured that will burn bituminous coal efficiently under ordinary conditions. Coke, being free from volatiles, gives smokeless combustion under the most adverse conditions.

Sootless.—Soot is unburned carbon—wasted heat. Soot deposit in the flues of heating appliances acts as an insulator, and makes it just so much harder for the heat to penetrate to the hot air and hot water chambers. Soot in stove pipes and chimneys is the cause of most chimney fires. Coke is sootless, and if burned in conjunction with coal will not only keep your flues and chimneys clean, but will actually clean them out if they are dirty.

Even Heat.—One of the big advantages of screened coke is its ability to give-off its heat steadily over long periods; while local coals throw-off an excessive amount of heat for a short time, and then die down. Coal burned in conjunction with coke benefits by this, and its combustion takes place slower and more evenly.

Economical.—The first price of coke is lower than that of good coal. Tests made at the University of Illinois show that 7¾ tons of coke equal 10 tons of coal. The reason for better results with coke is that nearly all the heat in coke is in the form of fixed carbon, which burns without waste (smoke) in the ordinary household appliance; while 30 p.ct. or more of the heat in most coals is in the form of volatiles (gas, tar, &c.), which are driven-off through the chimney in the form of smoke or deposited on the walls or flue pipes and smokestack in the form of soot.

Cleanliness.—On account of the absence of smoke and soot, the housewife will find it much easier to keep the house clean when burning coke. There will be no black streaks on the wallpaper over the registers. Curtains, draperies, &c., will not need washing as often. The windows will stay clean longer. Wallpapers will not have to be renewed as often. The chimney will not have to be cleaned at all; and the furnace flues need cleaning only at rare intervals. You will find no sooty or tarry deposits in the flues, but only very fine dust, which is easily removed.

Coke in Conjunction with Coal.—The Department of Mines, Ottawa, says: By burning coke with soft or bituminous coal, many of the disadvantages of the latter fuel are lessened. It is not necessary to poke the fire and charge fresh fuel as often, the deposit of soot on the hot water section is not as heavy, and the fuel will give-up its heat at a more uniform rate.

How We Meet Objections Encountered in Selling Screened Coke.

Price.—Coke is a manufactured fuel, and not a mere bye-product. When blending the coals used for making coke, special attention is paid to the coking quality and ash content of the different coals, and often a higher priced coal is bought which is a poorer gas producer, but gives the better coke. To secure 1 ton of coke for sale, it is necessary to carbonize about 2 tons of coal.

Damage to Furnace.—We cannot find any evidence of this at all. Screened coke is sufficiently high in ash to prevent any such damage being done, as long as it is used correctly. We know of one instance in particular where a mixture of coal and coke has been burned in a " Monarch " range continuously for twelve years in the same fire-pot, on the same bars.

Insufficient Heat.—It is poor policy to put a small amount of coke in your fire-box, and try to get the desired temperature by running with the draughts wide open. Always keep sufficient coke in your heating appliance to give you the necessary amount of heat with the draughts closed or nearly closed. It is of the utmost importance to use the proper size of coke for your appliance. When ordering coke, always state what you want to use it in.

Too Much Ash.—We have no control over the amount of ash in the coals used in the manufacture of coke. To keep the price of the finished product down, we have to use local coals; and the number of coals suitable for our purpose is very small, and their ash content is none too low. However, a certain amount of ash in the coke is beneficial, as it serves as a protection for the grate bars. The user can keep the ash down to a minimum by not shaking the furnace bars any more than is absolutely necessary, and never until the red-hot coke rests on your grate bars. This prevents small unburned particles of fuel from passing into the ashpit. After all, the most important thing to consider when buying fuel is not how much ash per ton, or how many B.Th.U. per ton, but how much *available* heat per dollar.

Clinkers.—Screened coke used intelligently will burn to a fine powdery ash. Clinkers are caused through excessive draught or shallow fire beds. In cases where there is an uncontrollable heavy draught, a smaller size coke should be used, so as to obtain a tightly packed fire bed that prevents the passage of excessive air. Whenever possible, carry a deep fire bed, and keep the draughts closed or nearly closed.

Selling Our Own Employees.

One of the most objectionable features we discovered at the outset was the utter apathy, and, even worse, the continuous disparaging criticism of our coke as a fuel, of a number of the Company's employees. Of course, the prime reason for this was ignorance. Some of the men in the Electrical Department, Street Car Department, or other parts of our service, had bought coke at times, and did not understand how to use it. Of course, they blamed the coke for their failure. We announced a special low summer rate for employees, and made a personal canvass of all the men. We undertook to show each purchaser how to use the coke in his own particular appliances, and also guaranteed to take it back if we could not satisfy him.

This campaign, coupled with personal letters and short articles in our " Employees' Magazine," has brought about a complete change in their attitude towards coke. The employees at large are beginning to realize that the Company are in the coke business just as much as in the gas and electric business, and also that they have a right to be just as proud of coke as they are of the Company's other products and services. It is of the utmost importance to sell your own employees on the idea of using coke, and keep them sold. No trouble or expense you go to to achieve this is too great. An indifferent or slighting remark made by an employee can easily turn a prospect on whom your salesman has worked for weeks.

Advertising.

The salesman's greatest help is judicious advertising; but it is essential that the closest co-operation between the selling and advertising departments be maintained. We make seasonable advertising appeals to the public, and when we ask a man to buy we show him why it is to his advantage to buy. It is not enough to say that coke is smokeless, sootless, and economical. We tell our customers about the tremendous waste of fuel that is represented in smoke, about the damage to interior decorations and draperies, about the quick deterioration of paints, &c., caused through smoke. We explain how soot is a heat insulator; how it causes chimney fires. Then we go on and show why a ton of coke delivers more B.Th.U. into the home than a ton of coal. The simplest language has to be used for all this, and every fact has to be driven home again and again.

We have no particular favourite among the various forms of advertising. We use them all for specific purposes. To put your product before your customer, and thoroughly explain

its advantages, there is nothing like a really attractive folder. A coke folder which was used last fall, and which brought in a swarm of orders, makes two distinct appeals—viz., cleanliness and economy—clinches the sale with the reproduction of an unsolicited testimonial from a customer. This folder was followed-up with a few quarter-page newspaper advertisements, and a month later with street-car cards. This proved a very economical and efficient campaign, resulting in a good percentage of telephone orders and a large number of inquiries, which were mostly turned into orders through a telephone call or a personal visit from a salesman. We use a number of bill boards at different places in the city; but they serve only as reminders. Their message must be snappy and outstanding, so that it will be read and grasped by the public whizzing by in automobiles and street cars.

ORDER YOUR COKE WHILE YOU'RE HERE
USE SCREENED COKE THE SOOTLESS AND SMOKELESS FUEL
SOOTLESS SMOKELESS
SCREENED COKE
for Economical
FURNACE FIREPLACE KITCHEN RANGE HEATER

Fig. 5.—Coke Display.

A large number of people pass through our showrooms every month, either to look at various appliances or to pay their bills. In a prominent position there, we place a coke display, as shown in fig. 5. An electric light is put under a wire cone, which is covered with red tissue paper. On this we build-up lumps of coke, and so obtain a most realistic effect of a coke fire. The cost of this display is trifling, when compared with the results.

To outside coal merchants we send form-letters and enclose samples of our folders, &c. Below is an example of such a letter. One-hundred-and-fifty copies only were mailed, and from the resulting inquiries we obtained orders for ten carloads.

Nov. 16, 1923.

Gentlemen,—If we were to offer you a moderately priced anthracite coal, you would be keen to buy from us. Unfortunately, the supply of anthracite is uncertain and the price high. There is, however, a manufactured fuel of equal heat value.

Screened coke is anthracite's full brother, and we can supply you with coke at a price that enables you to build-up a profitable business.

Your customers will like screened coke because it is a clean, smokeless fuel, and gives them more heat per dollar.

You will like it because it is easily sold, and means more money per ton to you.

Some dealer in your neighbourhood is going to make a handsome profit on the sale of our coke.

Our experience in merchandizing coke is at your service, and we will assist you to any reasonable extent in working-up your coke business.

Let us hear from you.

Yours truly,

Coke Department.

Advertising and Selling Costs.

Of course, it is interesting to know just what these sales and advertising efforts cost us. Our total advertising bill of last year amounted to 16c. per ton. Salesmen's salaries, commissions, and travelling expenses came to 60c. per ton, in which is also included the Sales Manager's and Shipper's salary, and all expenses incurred in service and follow-up work. This makes a total of 76c. per ton, which we regard as reasonable indeed, when you consider that our sales doubled in two years.

Delivery System.

When an order is secured through one of our various sales efforts, the coke is sent out as promptly as possible, mostly on the same day. To local customers it is delivered in bulk trucks, as shown in fig. 6, or on platform trucks in 100 lb. sacks. The bulk trucks have a 9½-yard steel dump body,

Fig. 6.—Coke Truck.

mounted on a 3½-ton chassis, and haul 4 tons in a load. Fig. 7 shows how the bodies are divided into four compartments, holding 1 ton each. The steel divisions are hung on hinges, and locked at the bottom, so that a ton at a time can be dumped or the whole load at once if necessary. The entire back of the body swings out when the load is dumped into a manhole. Where the coke has to be carried any distance into a customer's bin, the driver does not unlock the back door, but opens a small shoot in the back, and fills a basket at a time, which is carried in by his helpers.

Fig. 7.—Coke Truck Dumping.

This method of delivery is economical and adaptable to bulk deliveries, as well as single-ton deliveries. It eliminates sacking and the cost of sacks, and also cuts the loading time, as the truck simply drives into a platform scale below a shoot in the bunkers.

Follow-up and Service Work.

When the coke is delivered, the most important work of the Coke Department starts. The driver hands the customer a delivery slip, which gives the following short directions on how to use coke.

INSTRUCTIONS

As published by the Department of Mines.

Screened Coke.

Building the Fire.—To kindle this fuel it is necessary to build-up a good wood fire on the bare grates, and then charge enough coke to half fill the fire-pot. Leave the drafts and grid in the fire door open until the coke is well ignited and blue gas flames appear on the top of the fuel bed; then fill the firepot with coke, close the drafts, and partly close the grid in the fire door. To replenish the fire, shake the grate vigorously, and fill the fire-pot as before; do not alter the drafts.

To Bank the Fire for the Night.—Replenish the fire in the usual manner, and then charge as much more fuel as the furnace will hold.

Mixture of Screened Coke and Soft Coal.

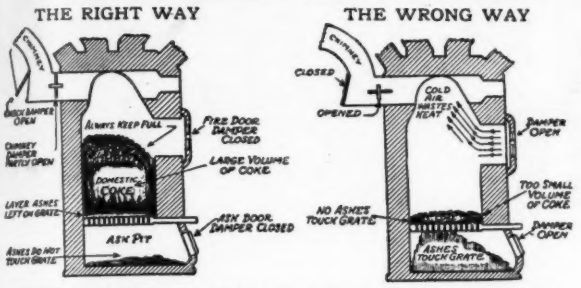
Build-up a good coke fire, and then charge an equal quantity of soft coal. The drafts should be open a little, and the grid in the fire door wide open. The soft coal will cake, but not to the extent it does when burnt alone. Therefore the fire does not require to be broken-up as frequently.

Bank the fire for the night by charging alternate layers of fuel, first coke, and then soft coal.

By burning coke with soft or bituminous coal many of the disadvantages of the latter fuel are lessened. It is not necessary to poke the fire and charge fresh fuel as often; the deposit of soot on the water sections is not as heavy; and the fuel will give-up its heat at a more uniform rate. The grid in the fire door must never be closed.

The driver also tacks-up a card, as shown in fig. 8, in a convenient spot near the customer's furnace.

How to Obtain Best Results from Screened Coke



TO START FIRE—Use plenty of wood; throw on a few shovelfuls of Screened Coke and open all drafts. When Coke takes fire, add enough Coke to make a good full bed. Keep the lumps small.

TO SLOW DOWN FIRE—If you have good bed of fire underneath you should immediately close drafts; shut ash door damper, close chimney, open check damper, open fire door damper if necessary. Your furnace will need no more attention for six hours or more.

SHAKE down fire once, or in cold weather twice, daily. Stop as soon as live coals appear. Always have layer of ashes on grate when fire is burning.

BANK fire at night by sprinkling fine coke or ashes on top of fire.

KEEP THE FIRE POT FULL AND OPERATE WITH VERY LITTLE DRAFT—and you will heat your house for less money.

Fig 8.—Instruction Card.

A copy of the delivery slip goes to the sales office, and a card as shown below is mailed to the customer. Then the shipment is entered on a file card, giving the customer's name, address, and telephone number.

Follow Up Card.

Dear Sir or Madam,—Your screened coke has been delivered, and we trust it is giving you entire satisfaction.

Properly used, screened coke will prove the cleanest and most economical fuel for all heating purposes.

If you have any difficulty in using it, telephone the Coke Department, and without expense or obligation on your part we will send a demonstrator to your home to show you the correct method of using coke.

Yours very truly,

Coke Department.

When a customer telephones a complaint, a personal call is made by a salesman, and usually an actual demonstration of the correct method of firing coke will overcome all difficulty. If after such a demonstration a customer is not satisfied, we take the coke back free of charge, and refund the money. We find that it pays to do so, even at considerable expense, because it leaves this customer in a more amiable mood, and he is not so liable to go out of his way to knock coke. As a matter of fact, this happens only once or twice a year.

Periodically the file cards are checked over by the domestic salesman, who telephones every customer who does not reorder within a reasonable length of time. To customers who have no telephone, and live in outlying districts, the following form-letter is mailed:

Dear Sir or Madam,—It is some time since you received your shipment of screened coke, and we are wondering why we have not heard from you lately.

Perhaps your supply is lasting out longer than we figured it would.

Perhaps you are using your coke in one appliance only, never realizing that it will burn equally satisfactorily and economically in range, furnace, heater, or fireplace.

Perhaps you are not entirely satisfied with the result you have obtained so far from screened coke.

Screened coke is a ———— product, and the Company stand behind it with a money-back guarantee. We have a well-organized complimentary service that will tell you just what kind of coke to use in your appliances, and how to fire it to the best advantage.

Why not avail yourself of this service?

Telephone the Coke Department, and let us talk it over.

Yours very truly,

Coke Department.

From time to time, usually three or four times a year, we send a personal form letter to all our coke customers—perhaps to wish them a Merry Christmas, or to announce a change in prices, or some improvement in the quality of our coke. One such letter, as reproduced below, is used to obtain testimonials for advertising purposes:

Dear Sir or Madam,—We *believe* that you are using screened coke in your home because you find it cleaner and more economical. We also *presume* that you are using it according to the instruction card which our driver left with you.

But we don't *know* for sure!

Perhaps the real reason that you are burning coke is something different altogether. Perhaps, instead of following the instruction card, you have developed a different and more economical method of firing coke that others would be glad to know about.

Why not write us a letter telling why you are a coke user, what grade of coke you are burning, and what heating appliance you are burning it in? Tell us how you are firing it, and, if you have the figures, also give the cost of heating your house.

A copy of this letter has been mailed to all coke users; and it is just possible that one of the thousands of replies we shall receive will disclose a method of firing more economical than yours. If so, we shall be pleased indeed to advise you.

We are,

Yours for fuel economy,

Coke Department.

P.S.—Remember that we are much more anxious to sell you heating comfort at a cost satisfactory to you than to have you buy many tons of coke at a cost that hurts.

Summary.

It is only fair to state that a good deal of credit for the increase in our coke sales is due to the preparation of the coke at the gas-works. No matter how thorough and how wide-awake a sales organization you employ, you cannot sell a water-soaked coke, improperly sized. We have made it a rule never to accept an order from a new customer without inquiring for what purpose he intends to use the coke, and our men are specially trained to give sound advice as to what sizes are most suitable for certain appliances. For instance, in the case of large office buildings and apartment houses, where we are up against the indifference of janitors and engineers, we never recommend straight coke as fuel, but always a mixture of coal and coke. The same holds true for high-pressure steam installations, except where a forced draught is provided or where the demand for steam is regular and rather low in proportion to the boiler capacity.

By using the ways and means described in this paper, we have doubled our sales in two years' time, and are adding this year another 25 p.ct. During the same time we have increased the price of coke about $1 per ton, and find sales easier at the higher price with the assistance of selling and advertising efforts. We have demonstrated to our own satisfaction that the most economical way to dispose of the coke is to spend the necessary money for advertising and selling efforts, and ask a fair price for such an excellent fuel. A persistent, aggressive sales effort is sure to increase the revenue from coke and keep the stocks down to a minimum.

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